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Proceedings of the Industry Advisory Group on Foot-and-Mouth Disease Washington, D.C., October 18-20, 1971

Animal and Plant Health Inspection Service
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PAPER NO. I—REPERCUSSIONS OF THE OCCURRENCE OF FOOT-AND-MOUTH DISEASE IN A DISEASE-FREE AREA

By F. J. Mulhern[1]

Those of us who have major responsibility for the prevention, control, and eradication of livestock diseases in the United States live in fear of the day when we wake up and the newspaper headlines proclaim "Foot and Mouth Disease Found in the U.S.A." This fear keeps us alert to prevent the disease from entering our country and helps us to be prepared to handle the outbreak should it occur.

Since we have not had the disease in the United States since 1929, some of us must rely on experience gained while engaged in the Mexico-United States Foot-and-Mouth Disease Eradication Program. I will try to visualize for you what I see the consequences might be if foot-and-mouth disease were introduced into the United States and, in some instances, compare them to what they were in Mexico at the time I was there.

I have heard persons from South America say that we in the United States are overly concerned with the importance of this disease. Our concern is purely economic. If we get the disease the annual vaccination bill alone would be over $100 million a year—not to eradicate, but to keep epidemics from developing. We haven't had the disease for 40 years, so the savings s quite evident. The cost of vaccine alone for that period would be over $4 billion. I will now try to project some of the other types of costs. I will not be able to place specific figures relative to them, but I believe you will realize the magnitude—it could be *in the billions!*

First, let's consider the susceptible livestock populations in the United States. There are over 105 million cattle and calves, over 54 million hogs and pigs, and over 25 million sheep and lambs. The value of these animals amounts to $19.7 billion. So, when we think of an outbreak, we immediately think of these multimillion populations of susceptible livestock.

Sometime ago I tried to show how vesicular exanthema, a virus disease of swine, spread across our country. I began to plot movements from all stockyards during a 1-week period. Before I could show movements from several stockyards, it became a confused mass. I had to settle for the movements from three stockyards during 1 week's time. Now, if you want to get some idea of the total situation, you must multiply this by 56 other stockyards under Federal inspection; and over 2,300 smaller auction markets, movements to and from the numerous concentration points, and movements to direct slaughter. So we not only have multimillion livestock population, but we have

[1] Deputy Administrator, Agricultural Research Service, U.S. Department of Agriculture. Speech given before the II Ministers of Agriculture Meeting in Rio de Janeiro, May 14-17, 1969.

multithousands of them on the move daily. All we need to do is to introduce an infected animal into that system and before we know it, the disease could be all over the United States.

Stopping Livestock Movements

Our livestock constantly moves in all directions. Since infected and exposed animals are the chief sources of spread, you can see the problem in trying to slow down, or stop, the spread of infection. However, in order to bring the disease under control and eradicate it, *this must be done.* The longer it takes to significantly slow down the movement of livestock, the greater the spread. The longer the time to bring the disease under control, the greater the costs.

We have a very complex livestock marketing system. The many facets, or units, within the system are all interrelated. Whenever one part of the system is affected, a reaction automatically occurs in some other part. Therefore, if and when action is taken to slow the movement of livestock, price fluctuations are bound to occur. Price fluctuations will probably result in shifting of markets—that is, people accustomed to shipping to one market will sell to another. Market shifting will also be used to try to avoid quarantines. Temporary panic selling develops and prices drop as large numbers of animals are sold in hopes of not getting caught in quarantines. Likewise, scare-markets can develop where people will hold back marketing of animals that are ready to go to market because they are afraid their animals may get caught in a quarantine. If this occurs to any degree, the price will skyrocket due to lack of animals. Naturally this will cause a violent reaction from housewives which will boomerang back to the Government.

In Mexico, the problem in stopping livestock movements was not as complicated, but reactions were the same. In addition, fear on the part of some owners caused them to drive their animals to faraway places. In some cases there were infected animals in their herds and they exposed others along the way. In many cases such movements were a major factor in the rapid spread of the disease. Seventeen States in central and southern Mexico became involved. I am sure that if we had an epidemic some owners would try to hide the disease and market animals not showing signs of disease.

When livestock movements are slowed, many people will be affected. It doesn't take too much thinking to realize that when the system slows up, people lose work, and allied industries that have been serving the system suffer. A chain reaction takes place. The Government hears complaints from all sides.

With the cooperation of their leaders, our livestock industry is being informed regarding the need to slow or stop movements in time of an emergency. Everyone should know ahead of time what must be done if an outbreak occurs. Now is the time to plan; we must not wait until an emergency occurs.

Stopping Meat Movements

So far we have just talked about that part of the system involved in the production and marketing of livestock. Now let's look at the end products—particularly *meat.*

There are more than 3,000 slaughter plants, each of which annually slaughters livestock with a live weight of more than 2 million pounds. There are 4,750 plants that slaughter over 300,000 pounds but less than 2 million pounds per year. There are a total of over 7,000 slaughtering establishments.

There are also 4,000 or more locker plants that process meat products for local sale.

The meat industry has a saying, "You either sell it or you smell it." In other words, once the livestock are slaughtered, the resulting products must move quickly to the consumer. Modern refrigerator and processing procedures have reduced some of the urgency to sell. However, the cost of any meat item is too great relative to the profit margin to risk loss from spoilage. So you can see the dilemma. We desire to slow the movement of livestock to halt the spread of animal disease, but this cannot be done without interfering with the operating practices of the industry.

Nevertheless, the same principle that applies to movement of meats and other animal products, applies to movement of live animals. In areas where the disease has been identified, the sooner movements of meats are slowed and eventually stopped, the better the chance of eradication at lowest costs and inconvenience to everyone.

The choice that has to be made is whether it is better to slow the movements, or even to bring them to a standstill, for a relatively short period of time and get rid of the disease, or to constantly interrupt the system due to outbreaks of the disease that would occur continuously if we decided to live with it. These added costs due to interruptions of trade because of periodic outbreaks would have to be passed on as operating expenses. Thus, the increased operating expenses would have to be charged in the price of meat to consumers. Our decision is to keep the country free of foot-and-mouth disease.

The meat packing industry hires over 229,000 people. When we slow, or stop, movements, people lose employment and this causes problems.

The meat industry was not as developed in Mexico as it is in the United States, but problems in the movement of meat occurred. The Government more or less controlled the greater movements of meat, especially from producing areas to larger cities, so that regulation of the meats was easier there than it would be in the United States. However, when shipments decreased because of the disease, prices rose and the people, or consumers, criticized the Government. The people living in outlying areas didn't eat much meat, but when it was taken from them as they were leaving quarantined areas, it was a very sad situation. Meats have been instrumental in causing many serious outbreaks, as all of us are aware, and that is why meats must be strictly controlled during an outbreak.

When we speak of effects on transportation of livestock and meats, we fully realize that transportation companies are deeply affected by our quarantine procedures. We have had experience in trying to control disease by cleaning and disinfecting vehicles after diseased animals have been hauled in them. When this approach was used we were always behind the disease. During an epidemic, livestock can only move in vehicles that have already been cleaned and disinfected. The same requirements apply to all feed, water, and rest stations where animals are unloaded enroute to their final destination. In our country this means that we must maintain close surveillance over hundreds of stations. Here again protests would be heard about added costs and inconvenience, but it would have to be done if the eradication program were successful.

This means that thousands of trucks (the meat industry alone uses 150,000) and railroad cars must be cleaned and disinfected each week during the epidemic. Transportation companies are willing to bear with this as long as dramatic disease reduction occurs, and there is a clear understanding that these restrictions will be removed as soon as possible.

In Mexico, cleaning and disinfecting stations for trucks and railroad cars were set up throughout quarantined areas, as well as along the borders. An exceptionally fine job was accomplished. Here again, the railroads were under Government control and good compliance was achieved. Trucks traveling along highways frequently are stopped by police checking for violations, therefore added precautions due to foot-and-mouth disease quarantine were more readily accepted by drivers than they would be by independent transportation companies in the United States.

Stopping Dairy Products

During the last outbreak in England it was learned that milk was a cause for the spread of disease. Foot-and-mouth virus actually was found in exceptionally high quantities in several of the bulk tanks located on infected farms. Here again we have another complex industry that must be brought under control during an epidemic.

Let's look at our dairy farms and where whole milk is sold. Here again we see large volumes of an animal byproduct on the move. The rapid method of pasteurization (161° F. for 15 seconds) doesn't kill foot-and-mouth virus, so in areas affected, we will either require condemnation of the milk or longer pasteurization temperatures (145° F. for 30 minutes). Naturally, the volume will determine the decision to be reached.

Other than the larger dairies around cities in Mexico, the movement of milk did not give the disease control officer much of a problem. Disturbing our dairy products marketing system could give us many problems. The value of our dairy products (milk and cream) is over $4 billion.

Here again we must be sure that those engaged in that industry appreciate the need to restrict movements during an epidemic.

The next area of interest is stopping movement of hay and animal feeds—namely corn, oats, and barley. These also must be brought under control during an epidemic period. Their movements are extensive, and market prices are quite sensitive to any changes that affect the sale of them. Therefore, great care must be exercised in applying necessary controls over them.

Here again, the Mexican Government did a good job in controlling movement of hay and other livestock feeds. I'm sure we will have much more difficulty with our system than they had with theirs.

I have singled out these four areas to give you some idea of the scope of the problem. All animal byproducts from the species of animals susceptible to foot-and-mouth disease are involved.

All Animal Byproducts Controlled

To give you some idea of the different types of animal byproducts that must be controlled, following is a partial list of those that we keep currently controlled when they are imported: Bones, bristles, casings, cream (liquid, powdered, and derivatives), feed for domestic animals and poultry, fertilizer, game trophies, gluestock, hair, hides, hoofs, horns, ice cream mix, manure, organisms and vectors, pharmaceuticals of animal origin, poultry (dressed), semen, skins (green salted, wet salted, dry, or raw), tankage, and wool.

During an epidemic, there would be similar controls on the movement of these byproducts from quarantine areas.

Diagnosis—Authority—Money

The Federal Government investigates every suspicious outbreak of a foreign disease in our country. If our specialist determines that a case is highly suspicious, we send the sample with him to Plum Island, our foot-and-mouth disease diagnostic laboratory. If the case proves to be foot-and-mouth disease, the States involved and the Federal Government would declare an emergency. Then we would be provided with a special source of funds and authority. It does likewise for the States.

Emergency Disease Organization

There is an emergency disease eradication organization in each State, consisting of both Federal and State government personnel. This would be placed into operation whenever necessary. This organization consists of inspection forces, information specialists, appraisers, diagnostic specialists, heavy equipment operators, enforcement officers, etc. Special arrangements have been made with different departments of government to get coordination from the different agencies in times when an emergency has been declared.

For example, under a tri-agency agreement, the Agricultural Research Service has the responsibility for directing and conducting animal-disease eradication programs, while the Department of Defense and General Services Administration (GSA) agree to provide supplies, equipment, and services necessary for carrying out the programs.

GSA has assembled kits of materials and placed them at strategic points throughout the country to save time should they be needed quickly. Included in the kits are such items as shovels, picks, air-filtering masks, first aid kits, barbed wire, disinfectants, and rubber apparel (gloves, hats, coats, and boots).

The logistics of getting thousands of persons and all the equipment in the right places at the right time is a tremendous challenge. As you can imagine, it doesn't run smoothly but usually works itself out, largely depending on the preplanning done.

Periodically, alert exercises are run to determine problem areas so that adjustments can be made in the program. In these exercises, industry leaders observe operations so they can propose ways to accomplish our goals with the minimum adverse effect on them.

Program Phases

The emergency usually goes through three phases. The first phase I call the *hysterical, or panic, stage.* People can't understand the rapid spread. It seems to be everywhere. They demand that everything be done to bring the disease under control. Sometimes they take it to extremes. I recall some of our ranchers demanding that we build a fence along the Canadian border when foot-and-mouth disease was found in Canada in 1952. They wanted this fence built despite the fact that we have always had freedom of movement between our two countries.

Phase two, I call the *cooperative stage.* This is when those in the quarantine areas understand how the disease entered the country, how it was spread, and accept the restrictions being taken to control and eradicate the disease. This is a time when the best cooperation is received. Also, this is the phase when the greatest progress is made.

Phase three, I call the *impatient and apathetic stage.* The disease incidence has been dramatically reduced. In fact, many people living within the quarantined area believe that it already has been eradicated. Some of them even claim that the only reason for continuance of the program is that control officials have found good jobs and don't want to give them up. They are impatient regarding controls and want to get rid of them.

Some people within the area have become involved in other problems and are indifferent towards the program in this stage. If they are ranchers or producers who at one time inspected their livestock often to be sure they were not coming down with the disease, now they don't want to be bothered. They have looked at their animals so many times and found nothing wrong that they don't want to continue the effort.

Yet, this is the time that warrants closest surveillance to find the last remnants of infection. Unless this job is thorough and meticulous, the whole effort and cost are to no avail. Eradication means "to pluck out by its roots," and that means getting to the very core of that which can cause the disease to be perpetuated. It is an exasperating experience, but it determines whether the whole program is successful or not.

Good Information—A Must

How to handle television, radio, and the press can be a major task. Yet, if information work is not planned and its importance appreciated, repercussions can be tremendous. Because of our concern that those involved in communications not be responsible for spreading disease, it takes a great deal of empathy on the part of control officials to communicate this point when restricting their movements. We know they must get their information, and they want to be where the action is and talk to the people involved. We must give them this opportunity, but do it in such a manner that it has minimum effect on our program activities and does not spread infection.

This gets our primary attention, especially in the early phase of the program. Information people can get the program off to a good start, or they give program officials so much trouble that more time will be spent trying to placate them than getting the disease under control.

The general public eagerly will be wanting to know who was responsible for the disease being introduced. In my opinion, too much time and effort are spent during this phase of the program trying to find and punish the person, or persons, responsible for allowing the disease to be introduced. In the early stages, we need all our efforts directed at getting the disease under control, and not divided by those who want revenge. There will be time for that later.

This is the time when the Government is exercising various controls over commodities mentioned earlier. This is a prime time for those who don't like any infringement or restriction on their freedoms to challenge actions of their Government. They want the disease brought under control by any means, but don't restrict them on their vested interests.

Quite often during this period there are charges and countercharges being made as to how the program is being run. It is unfortunate that this occurs, because it sows seeds of doubt in the minds of industry leaders involved about those who are conducting the program. Good communication leads to the mutual confidence essential between industry and its government if the disease is to be brought under control in the most effective and efficient manner.

Eradication—Not An Easy Goal

There is never a time for compromise if the goal is eradication. What needs to be done, must be done. *Everybody must* be treated the same. If the movement of animals and animal byproducts must stop, or be restricted, it must apply equally to all.

Eradication procedures are well proven in all countries that have gotten rid of the disease. They are very demanding, however, and require sacrifice by all involved. The rewards are worth it.

Believe me, there were times in Mexico when we wondered if eradication would be accomplished. There were times when we, the Mexican and U.S. Government officials, could not understand how the situation got so bad. Our people were working day and night to get the disease under control, but it was still spreading. The people, especially those who lived in outlying areas, didn't understand the program—in fact, some of our people were being killed (both Mexican and United States citizens). All we got was criticism from all directions. Many times we faced the question—Is it worth it?

Today, since Mexico has not had a single case from the year 1954 to the present time, Mexican officials and those who were there from the United States know now that it was worth it. Not only this, but it has inspired us, that despite the odds against eradication, it *can* be done if there is the will to do so.

In summary, foot-and-mouth disease can upset the whole economy of a country that is free of it. I have tried to show the complexity of the marketing systems of some of our commodities that would be involved. Despite their size and importance, they must be controlled if we are ever to eradicate diseases such as foot-and-mouth, should it enter our country. We cannot afford to compromise with eradication procedures that have proven successful. Our economy is not willing to live with a disease like foot-and-mouth. We are not willing to accept the costs and losses from such a disease as this, as an operating expense—not when we know it can be eradicated.

There may have been times when you wondered why we take the approach to this disease that we do. I have heard it said that we do so just to protect our home markets. I can assure you that this is not so. If anyone believes that this is so, I hope my presentation has made it clear that our position is based solely on a decision that we don't want to be faced with the consequences of eradicating this disease. Therefore, we take all measures we believe necessary to keep it out of our country.

PAPER NO. 2—FOOT-AND-MOUTH DISEASE—A REVIEW

By J. J. Callis, P. D. McKercher, and J. H. Graves[1]

Foot-and-mouth disease (FMD) is a viral disease of cattle, swine, sheep, goats, and other cloven-footed animals. What was probably FMD in cattle was first described in Italy in 1546. In 1897, the causative agent was isolated and determined to be a virus, which later was shown to be about 23 millimicron [1:25 millionths of an inch] in diameter. Foot-and-mouth disease is probably the most infective disease of farm animals, making it one of the most difficult epizootiologic problems in animal virology. Its high infectivity in several species, its ability to spread rapidly, its widespread distribution, and its plurality of serotypes are characteristics which make FMD difficult to control. Wherever FMD exists, it interferes with import and export trade in animals and animal products. The manner in which every animal product offered for commerce on the world market is handled is in some way influenced by FMD. Entry of products from enzootic areas into FMD-free countries is either prohibited or so severely restricted that the price is affected. Because of interference from FMD in world trade, the disease has, on occasion, been called a "political disease." However, the problems which result from controlling FMD are real as well as political. Each new epizootic is widely publicized, and often much criticism is directed at those responsible for controlling it. In spite of its long history, the public's awareness, and quarantine methods used by many countries, effective control cannot be claimed in more than a few parts of the world.

Foot-and-mouth disease occurs in all of the large land masses of the world, with the exception of North America, Australia, and New Zealand. It has not occurred in North America since 1953 when it was eradicated in Mexico. It last occurred in Canada in 1952, in the United States in 1929, and in Australia in 1872. The disease has never occurred in New Zealand. The United States has had 9 epizootics, the first in 1870 and the last in 1929. The number of animals involved approximated 350,000, and direct and indirect costs approximated $175 million.

Natural infection is limited to cloven-footed animals, domestic and wild. Experimentally, the virus can be propagated in other species, including dogs, cats, chickens, rats, mice, rabbits, and guinea pigs. The horse has never been infected naturally or experimentally. The disease exists in a wide variety of wildlife, including deer, antelope, pigs, and buffaloes, any of which may pose a threat to control of infection during an epizootic. Man is rarely affected; thus the disease is not considered a public health problem.

Foot-and-mouth disease virus was the first known to have different serotypes. Recovery from infection with one type left the animal susceptible to infection with the other types. There are 7 known virus types. There are 3 classic types—O, A, and C; and 3 recovered from animals in Africa designated as SAT-1, -2, and -3. The 7th type, isolated from animals in Pakistan, is designated Asia-1. The significance of these virus types is important in preparing vaccines. In addition to the distinct immunologic serotypes, there are strains or subtypes of the virus within each serotype group. Differences between subtypes necessitate using field strains in preparing vaccines to achieve maximum protection. There are now approximately 50 subtypes within the 7 serotypes of the virus. Europe and South America have types A, O, and C; types SAT-1, SAT-2, and SAT-3 are found in Africa. In 1962, type SAT-1 was found in the Middle East. Type Asia-1 is found in parts of Asia and the Middle East.

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[1] This article was published in the Journal of American Veterinary Medical Association, 153 (12): 1798-1802, December 1968.

The 1967-1968 epizootic in Great Britain was caused by type O, subtype 1 virus. This particular subtype is scattered widely throughout Europe and Latin America; thus it is difficult to state with certainty where the virus responsible for the British epizootic originated. According to British veterinary authorities, there is circumstantial evidence that the virus may have gained entry by way of frozen mutton from Argentina. Information has recently been received from Argentina that the FMD vaccination campaign in that country has been extended to sheep.

The virus may be transmitted easily because of its ability to survive under differing environmental conditions. Man is an important factor in transmitting the disease. Although he is only rarely infected, he may mechanically transmit the virus. Modern transportation has substantially increased the probability of transmission. Other non-naturally susceptible animals such as cats, dogs, and rats may transmit the virus to susceptible animals. The disease, however, is most often transmitted by an infected animal or by a product from an infected animal. Saliva, semen, and urine contain the virus before clinical signs appear. Virus in milk was believed particularly responsible for the recent spread of FMD in Great Britain.

Biologic carriers among animals recovered from FMD infection have been suspected by field workers for many years. As early as 1931, workers reported isolation of FMD virus from convalescent cattle. In 1959, these findings were substantiated by recovery of FMD virus over a period of several months in saliva from recovered cattle. There is now ample evidence available to indicate that a large percentage of cattle recovered from infection of FMD become carriers of the virus for several months. Virus may be readily isolated from the esophageal-pharyngeal fluid from such animals. The sample obtained from the anterior portion of the esophagus by using a cup probang consists of mucus, desquamated epithelium, and food particles together with virus. The sample is referred to as esophageal-pharyngeal fluid. The role of the carrier in the epizootiology of the disease remains to be clarified, for researchers have not yet demonstrated contact transmission from carriers to susceptible animals. Cattle, sheep, and goats, but no swine, have been shown to be carriers.

In many countries, meat from infected animals is hung in refrigerator stores for a minimum of 48 hours, during which time the formation of lactic acid in the normal course of the ripening of meat supposedly renders the carcass virus-free. In these cases, the virus in the lymph nodes and the bone marrow is not reached by the acid, and thus the carcass remains a potential source of infection. In the event that the carcass is frozen, the formation of lactic acid is usually hindered; thus even the carcass meat may remain a source of infection.

The best and most effective means of controlling FMD is to keep it out of a country; therefore, countries that are largely self-sufficient, insofar as livestock production is concerned, rigidly control the importation of animals and animal products from infected countries. Such controls include regulations on the disposal of garbage from ships and aircraft originating in foreign countries.

In countries where FMD is enzootic, eradication by slaughtering infected and exposed animals is usually not considered practical. In such countries, slaughter of isolated herds is recommended only in special cases. This control method has not eliminated the disease in Europe. The aim of eradication of the disease has been relegated to the background in favor of the aim of limiting the losses to an economically bearable level. In countries where slaughter is regarded as impractical, other methods of control must be utilized. However, the aim of eradication must not be forgotten. A coordinated control effort, either by slaughter or by vaccination, has never been carried out throughout the European continent. The question also arises as to whether Europe would remain free because of the need for extensive importation of foodstuffs.

When a country has FMD there are 2 possibilities of control directed at eradication—the stamping-out method or vaccination, or both. In either case, application must be consistent and persistent. Haphazard vaccination only brings discredit to this valuable aspect of control. Where the disease cannot be controlled through slaughter, vaccination must be applied.

Methods of immunization against FMD have a long history. Various methods of active and passive immunization were tried, such as using convalescent serum, simultaneous serum and virus injection, and inoculation of live viruses in nonsusceptible tissues. Generally, these methods failed.

In 1937, research workers induced immunity in cattle, using FMD virus inactivated with formalin. About the same time, a Danish investigator was studying the action of aluminum hydroxide gel as an adjuvant for diphtheria vaccine. Subsequently, through collaboration, an FMD vaccine was developed in which the virus was inactivated with formalin after adsorption onto aluminum hydroxide gel. Since then, most of the FMD vaccines that have been used have been modifications of this development. Perhaps the next most significant development in the production of FMD vaccine was the discovery in the Netherlands in 1951 that FMD virus could be produced in cultures of surviving bovine tongue epithelium. This method had the distinct advantage of avoiding the difficulties involved in producing virus in live animals. Although the method was not received with enthusiasm, most of the FMD vaccine in the world today is produced from virus propagated by the Frenkel technique. In 1955, the virus of FMD was shown to propagate in primary tissue cultures of kidney cells from various species. More recently, it has been found that the virus will grow in cultures of cell lines from sources such as the baby hamster kidney. Such cultures can be produced in large quantities in the laboratory without the necessity of getting new tissues from the slaughterhouse. Large-scale tissue culture production techniques have been developed.

As mentioned previously, in countries where FMD is enzootic, vaccination is often used in an attempt to reduce the rate of infection to an economically acceptable level. Vaccination may be used as an adjunct to eradication to create an immune barrier between infected and susceptible animals while eradication progresses.

There are 3 essential features of a satisfactory FMD vaccine toward which research has been and is still being directed. These are safety, effectiveness, and cost. Foot-and-mouth disease vaccine must be so safe that the probability of causing the disease in vaccinated animals does not exist. The vaccine must be sufficiently effective so that a single dose produces enduring immunity in all of the susceptible domestic species. Production methods must permit vaccination of large numbers of animals economically. Most of the vaccines in general use in the world today fail in one or more of these categories. When properly applied, many existing vaccines are effective in reducing the incidence of the disease. However, immune cattle may also become carriers after exposure to the virus. Such animals remain free of clinical signs of FMD infection, yet virus replicates in the pharynx. This is one reason, when dealing with the disease in enzootic areas, that vaccination is recommended until the incidence of the disease is reduced to such a level that eradication by slaughter becomes economically feasible.

During the last few years, research workers at several locations have introduced innovations to the vaccine that appear to satisfy some of the requirements of a better immunizing agent. They discovered that acetylethyleneimine inactivates FMD virus, and this virus retains a high level of immunizing capabilities. Other workers used incomplete Freund adjuvant, arlacel A, and bayol F in the ration of 1 to 9 instead of aluminum hydroxide as an adjuvant. They found that this particular adjuvant seemed to enhance and prolong the immunity in cattle and pigs.

More recently, others have investigated a vaccine containing tissue culture-propagated virus inactivated with acetylaziridine and containing incomplete Freund's adjuvant. This combination, in a 2-ml. dose, produces a better and longer-lasting immunity in cattle, sheep, and swine than has been produced with the Vallee-Schmidt-Waldmann product. This particular formulation is being investigated in a number of laboratories around the world. The results of these studies are anxiously anticipated in hopes that this newer formulation will provide a better product than has thus far been available. In this event and provided this product is widely used in areas where efforts are made to control disease incidence through vaccination, this costly livestock infection may be reduced to a level where slaughter methods are practical even in enzootic areas. Thus, areas that have not been free of the infection may ultimately become so.

PAPER NO. 3—FOOT-AND-MOUTH DISEASE VIRUS AND VACCINES

By Howard L. Bachrach

This paper on foot-and-mouth disease virus (FMDV) and vaccines is in four parts: I.—Problems in vaccination caused by the high multiplicity of virus types and hosts; II.—Modified live-virus vaccines vs. inactivated virus vaccines; purification and properties of the virus; III.—Application of inactivated virus vaccines; and IV.—Experimental inactivated vaccines for swine (and cattle).

I.—Problems in Vaccination Caused by the High Multiplicity of Virus Types and Hosts

The multiplicity of immunological types (7) and subtypes (61: European O_{1-11}, A_{1-32}, C_{1-5}; South Africa I_{1-7}, II_{1-3}, III_{1-4}; Asia 1_{1-3}) and of virus hosts (cattle, swine, sheep, goats, deer, alpaca, vicuna, llama, antelope, gazelle, giraffe, water buffalo, bison, moose, elk, camel, chamois and other cloven-hoofed animals) makes the vaccination against FMDV a complex problem especially when modified live-virus vaccines are used. The complexity of this disease contrasts sharply with poliomyelitis in which there are three immunological types and one natural host (man), or with hog cholera where there is a single immunological type in a single host. In addition to the complexity of viruses and hosts in FMD, the problem of control is increased by a very high rate of contagion, the existence of disease on all continents except North America and Australia, the short duration of immunity (1 to 3 years in cattle and less than 7 months in swine), the carrier state of the disease, the difficulty of field application of vaccines to so many hosts and the instability of some vaccines.

II.—Modified Live-Virus Vaccines vs. Inactivated Virus Vaccines and Purification and Properties of the Virus

Despite these many problems there has been progress in the control of FMD in Europe and some other areas of the world by immunization with vaccines. The least success has been obtained with modified live-virus vaccines. Various modified virus vaccines have been obtained by the simultaneous infection of cattle with vaccinia and FMDV (Belin), or by serial passage of virus through unnatural hosts such as embryonated chicken eggs, day-old chicks, suckling mice, rabbits or tissue cultures. At present, Venezuela is the only country using modified live-virus vaccine; it is a bivalent vaccine comprised of virus types A_{24} and O_1 Campos modified in chick embryos and then produced in embryonated chicken eggs or suckling mice. Formerly, the production was in day-old chicks. Because of the carrier state of the disease, the high variability in the virus and other factors, European countries have agreed not to use modified live-virus vaccines. Some of the problems which have occurred are: (1) virus modified by passage through mice at Pirbright, England, gave a reasonable protection in laboratory experiments but less than the desired protection in field trials in Africa; (2) a mouse-passaged virus which produced acceptable immunity in Devon steers at Pirbright produced postvaccinal teat lesions when used in Israel to protect high-yielding Friesian cows; and (3) virus modified in West Germany by serial passage through approximately 600 tissue cultures was innocuous and immunogenic for cattle but still virulent for swine. The problems 1-3 above point up, respectively, the complicating effects of breed, sex and species on the activity of modified live-virus vaccines. In spite of these setbacks, recent research on the population genetics of viruses provides hope that temperature sensitive (ts) mutants or ts mutants

recombined with field virus may yet provide modified live virus vaccines of the type required for controlling FMD.

Immunization of cattle with inactivated virus vaccine has met with greater success. The vaccine was developed by Schmidt-Waldmann in Denmark and Germany from 1936-1938, and it was improved by Frenkel in 1951 and more recently by investigators in several countries. The basic vaccine consists of virus adsorbed onto finely-dispersed aluminum hydroxide gel particles and inactivated with formaldehyde. The source of virus for the Schmidt-Waldmann vaccine is the infectious lymph and lingual epithelium from artifically infected cattle; the Frenkel vaccine uses virus propagated *in vitro* in surviving strips of bovine tongue epithelium; virus for the more recent vaccines is propagated in baby hamster kidney, passage 21, clone 13 cells (BHK-21) grown either on glass in rolling bottles or in suspension in tanks. In one vaccine plant in Italy these cells are routinely grown on the glass surfaces of 28,000 rolling bottles (2 liter capacity), and the Burroughs-Wellcome Foundation has eight installations throughout Europe, Africa and South America which grow the BHK-21 cells in submerged cultures up to 2,000 liters in volume. The Plum Island Laboratory has an experimental rolling bottle facility for growing BHK-21 cells with a capacity up to 2,000 bottles.

Some of the experimental vaccines produced at Plum Island require purification and concentration of the virus. This is accomplished by precipitation of the virus with alcohols, extraction with organic solvents and centrifugation through sucrose or cesium chloride solutions (the virus forms a band in cesium chloride solutions at an isodensity 1f 1.43 g/ml). Electron micrographic examination of the purified virus shows it to be a polyhedron with a diameter of about 23 milliomitron (1:25 millionths of an inch), with probably 32 capsomeres (equally spaced morphological projections) on its surface. The purified virus, which is comprised of 69 percent protein and 31 percent RNA, can be broken down into protein subunits and infectious RNA by treatment with acids, phenol or by boiling at 100° for 5 minutes. Approximately one-tenth of a gram of purified virus is produced at Plum Island per week for use in biochemical and vaccine studies. The concentration and intactness of this purified virus is readily determined by analytical ultracentrifugation and by observing its ultraviolet absorption as a function of temperature changes. The purified virus contains principally 4 different proteins, one of which is nickable by the enzyme trypsin when it is still in the virus particle. Trypsin-nicked virus particles possess 5 proteins because of the splitting of one of the native proteins into two fragments. The trypsin-nicked particles have a low infectivity for some substrates, and a much lowered ability to produce neutralizing antibody in guinea pigs.

In many recent vaccines, acetylethyleneimine (AEI) at 0.05 percent concentration or other derivatives of ethyleneimine are used to inactivate the virus because the inactivation kinetics are essentially first-order, in contrast to the complex kinetics when formaldehyde is used. Inactivation by first-order kinetics makes it possible to predict more accurately when inactivation has reached statistically safe limits.

III.—Application of Inactivated Vaccines

A prime example of the use of inactivated FMDV vaccine has been in Holland where all cattle more than 4 months old have been vaccinated each spring since 1953 with Frenkel trivalent vaccine containing virus types A, O and C; all stock to be removed from the farms are revaccinated in the autumn. This long practiced and extensive systematic revaccination program for cattle in Holland and similar programs in other European countries has been responsible for a remarkable decrease of FMD in that area of the world. It was anticipated that this suppression of FMD in cattle would also reduce the incidence of the disease in swine, and this appeared to be realized until 1961 when there was an increase in the number of virulent outbreaks of FMD in swine, especially of type C virus. Swine had not been included in the systematic vaccination programs because they were poorly immunized with cattle vaccines. In Europe the use of such vaccines for swine is now restricted to quelling outbreaks, and 4 to 16 times the cattle dose is required. Even then, the immunity lasts for only about 3 to 4 weeks, and this period is not lengthened appreciably by the addition of saponin to the vaccine. These poor results in swine led Michelsen in Denmark in 1960 to conclude that a really effective immunization of swine could not be achieved with aluminum hydroxide gel as the

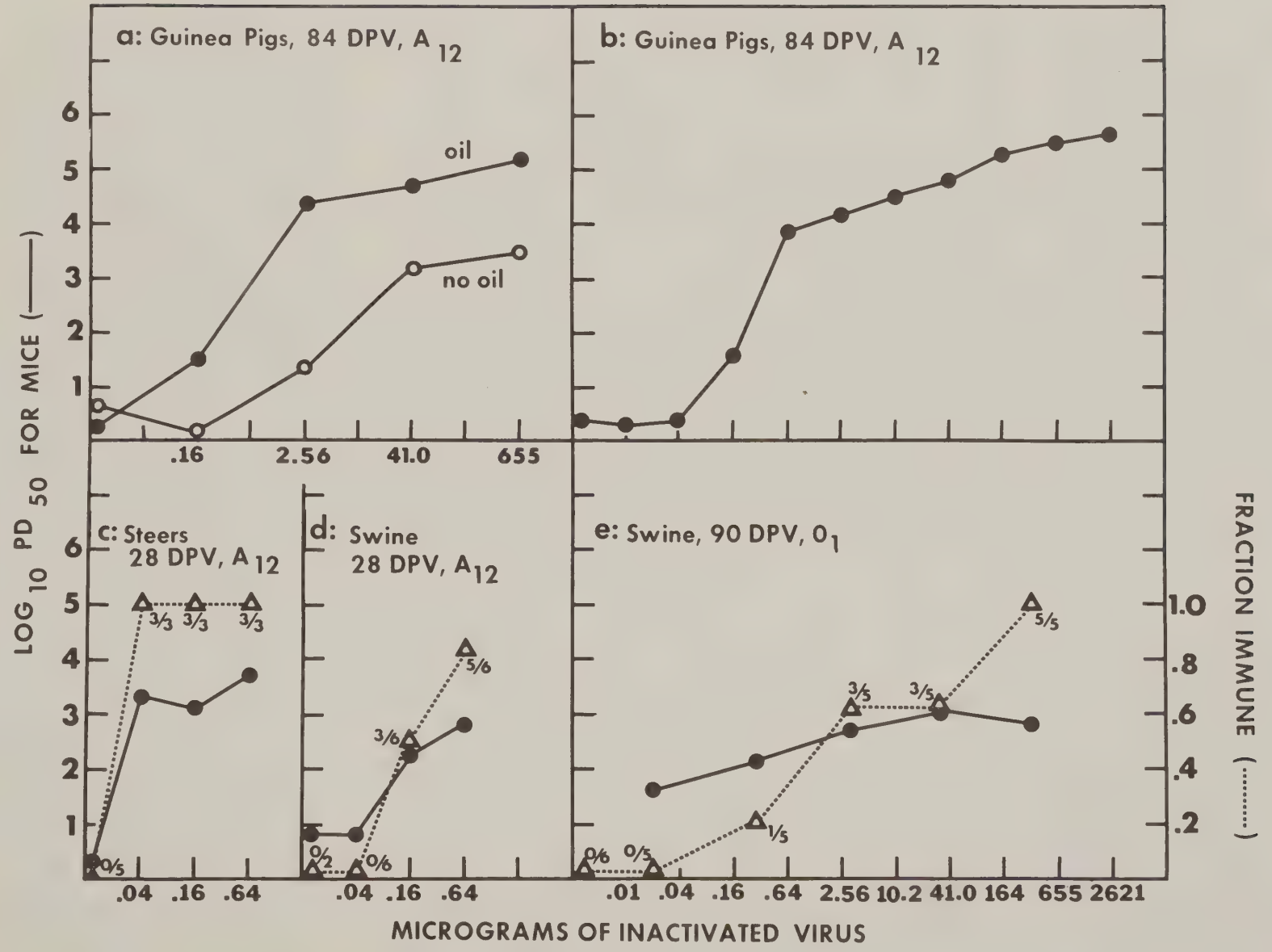
adjuvant. Workers in West Germany also concluded that the formaldehyde-inactivant in general use promoted structural changes in the virus, making it an unsatisfactory immunogen for swine.

IV.—Experimental Inactivated Vaccines for Swine (and Cattle)

A vaccine for pigs is required which, when administered immediately after the period of protection induced by maternal antibody, will protect them to the marketable age of 6 months. Breeding stock would be vaccinated twice yearly. The duration of immunity produced by such a vaccine would possibly have to exceed that of swine convalescing normally from clinical disease wherein immunity begins to subside as early as 3 to 4 months, and within 3 to 11 months about 50 percent of the pigs lose their immunity.

Several experimental vaccines have been formulated which are potent enough for the immunization of swine. They generally contain more antigen than cattle vaccines and are adjuvanted with mineral oil or with diethyl-aminoethyl (DEAE)-dextran with or without the addition of the double-stranded synthetic polyribonucleic acid, poly I:C. Michelsen in Denmark and Nathans in Holland both obtained somewhat better immunity in swine with formaldehyde-inactivated virus emulsified in mineral oil than with aluminum hydroxide as the adjuvant. McKercher and co-workers at Plum Island using AEI rather than formaldehyde as the inactivant for monovalent and trivalent vaccines emulsified in mineral oil succeeded in protecting swine for as long as 6 months against contact exposure to infected swine. The percentage of swine protected was twice that of animals that had recovered from experimentally induced infection. At 12 months some protection remained despite a marked decrease in neutralizing antibody; swine revaccinated at 6 months were protected for at least another 6 months. This oil-adjuvant swine vaccine was also shown to be effective in cattle in small scale trials at the Pan American Foot-and-Mouth Disease Center in Rio de Janeiro (cooperative project with Plum Island). Cattle were vaccinated with an AEI-oil-adjuvant trivalent vaccine comprised of O_1, A_{24} and C_3 subtype viruses. Revaccination was carried out at 6 months. Antibody titers and immunity of the steers were determined at appropriate intervals. The mean antibody levels in the animals after vaccination against the O_1, A_{24} and C_3 viruses were 1.7, 3.6 and 2.1 log units, respectively; after revaccination these values increased to 3.7, 4.4 and 3.1. Thus, the poorest antibody level (1.7 for O_1) was increased by the greatest amount by the revaccination process. Immunity of the vaccinated cattle (16 animals per group) was challenged with virulent type O_1 virus at 1, 4 and 6 months after vaccination as well as at 6 and 12 months after revaccination. The per cent of those immune after 1, 4 and 6 months was 81, 75 and 81 percent, respectively. The percent immune at 6 and 12 months after revaccination was 94 and 64 percent, respectively. (Some adjustment may be needed in evaluating the immunity of the vaccinated animals since 4 out of 40 or 10% of the control cattle were found to be immune). Nevertheless, it appears that the swine vaccine was very effective in cattle, so much so that the Pan American Center has projected a field test of the vaccine in about 10,000 cattle.

The availability of purified virus in decigram amounts at Plum Island has permitted the study of the antibody and immunogenic responses of guinea pigs, steers and swine as a function of the weight of virus in AEI-oil vaccines administered subcutaneously (fig. 1a-e). The amounts of inactivated virus subtype A_{12}, strain 119, ranged from 0.01 micrograms (μg) to as high as 2.62 milligrams (mg) in 4- or 16-fold increments; virus subtype O_1, strain Brugge, ranged from 0.02 μg to 416 μg in 12-fold increments. By 84 days postvaccination (DPV), the presence of the oil adjuvant had greatly increased the antibody responses of guinea pigs to 0.16 μg and larger doses of antigen (fig. 1a). Figure 1b shows another trial in guinea pigs covering the entire range of the subtype A_{12} viral antigen; 0.16 μg was again the minimum amount of antigen eliciting a measurable antibody response at 84 DPV, and the amount of antigen evoking a maximum response appears to be in excess of 2.62 mg. Only 3 antigen doses of A_{12} vaccine were tested in cattle and swine (fig. 1c and d). The minimum amount of antigen required to protect steers at 28 DPV, 0.04 μg, was significantly less than the 0.16 μg required for swine. Although not shown in figure 1d, swine vaccinated with 0.64 μg of the A_{12} vaccine were about equally resistant to challenge with subtype A_{24} and A-CANEFA-1 virus as to challenge with the homologous A_{12} subtype.



Immunity (·····) and/or neutralizing antibody (50 percent protective dose for mice) (———) in guinea pigs, steers and swine vaccinated with the indicated amounts of purified FMDV inactivated with 0.05 percent AEI and emulsified in oil (9 parts Bayol F or equivalent: 1 part Arlacel A). *a,b:* antibody responses in guinea pigs (5 per antigen dose group) at 84 DPV with type A_{12}, strain 119 vaccines with (O) and without (O) emulsification in oil. *c:* immune and antibody responses in steers (3 per antigen dose group) at 28 DPV to type A_{12}, strain 119 vaccines. *d:* immune and antibody responses in swine (6 per antigen dose group) at 28 DPV to type A_{12}, strain 119 vaccines. *e*: immune and antibody responses in swine (5 per antigen dose group) at 90 DPV to type O_1, strain Brugge vaccines.

Figure 1e shows antibody-antigen and immunity-antigen response curves at 90 DPV in swine vaccinated with 0.25 ml of subtype O_1 AEI-oil vaccines. Approximately 3 μg of antigen was required to protect 50 percent of the swine, and 416 μg was required to protect all of the swine. These results when compared with those in Fig. 1d indicate that type O_1 virus is a much weaker immunogen for swine on a weight basis than subtype A_{12} virus; it is also generally a poorer immunogen than type C virus.

While the AEI-oil vaccines meet the stated requirements for the immunization of swine, there is the disadvantage that large doses of these vaccines contain enough oil to produce objectionable sterile lesions at the site of inoculation in swine. With 3 to 6 ml doses of vaccine, oil vacuoles and granulomatous tissue are present 3 months postvaccination. These regress to spherical nodules and small islands of tissue by 6 months, and by 12 months the residual blemish is difficult to detect. The use of highly concentrated purified subtype O_1 virus (3 mg/ml) used in the experiment shown in figure 1e allowed the vaccine volume to be reduced to 0.25 ml (i.e., one-half of this volume was comprised of inactivated virus and one-half was oil adjuvant). This small dosage volume greatly reduced the tissue reaction at the vaccination site, and the use of the back of the ear markedly enhanced the possibility of using an oil adjuvant in swine under field conditions. The results with the purified and concentrated oil adjuvant vaccine have been so promising that the British are now testing such vaccines in about 10,000 swine in Hong Kong.

Wittmann and co-workers in West Germany have described an experimental ethylethyleneimine-inactivated vaccine for swine using DEAE-dextran rather than oil as the adjuvant. This vaccine appears to produce less tissue reaction but shorter immunity than the oil adjuvant vaccines. Strong immunity persists for about 12 weeks but after 16-18 weeks immunity diminishes and by 24 weeks, 50 percent or fewer of the animals are protected. Maes and co-workers at the Pan American Foot-and-Mouth Disease Center in Brazil report that the addition of poly I:C to the DEAE-dextran enhances the immunogenicity for swine of the Wittmann-type vaccine. At present, however, the cost of poly I:C ($3,000/gram) is a practical obstacle to its use on a large scale.

In the discussion period several points were made: (1) Inactivated vaccine *per se* does not induce the carrier state of the disease. However, vaccinated animals may become carriers when they are exposed to virulent virus; cattle convalescing from the disease may also become carriers. The term carrier does not necessarily infer ability to transmit disease, and transmission may be a rare event. Circumstantial epidemiology evidence led the Swiss about 1920 to forbid the stocking of susceptible herds with recovered animals until eight months after their recovery. In repeated laboratory trials it has been impossible to prove that carriers transmit the disease to susceptible contact animals. Carrier steers appear, however, to have transmitted an immunity to some swine without any overt signs of FMD; this was observed in a single trial at Plum Island and it needs to be confirmed; (2) There is both epidemiological and experimental evidence which indicates that mutant FMD viruses become established in partially immune animals which are continually exposed to virulent virus; (3) In contrast to cattle, there is no post-convalescent carrier state of the disease in swine; and (4) The safety of an inactivated FMDV vaccine can be determined from statistical considerations. Provided that the inactivation rate is first-order and that this rate extrapolates beyond the experimental data, then the time required for inactivation can be estimated from the number of animals to be vaccinated and the volume of the vaccine that each will receive. A vaccine exists for influenza which contains only the hemagglutinin portion of the virus from which all ribonucleic acid has been removed. A similar vaccine for FMD is not presently available.

PAPER NO. 4—FOOT-AND-MOUTH DISEASE CARRIER STATUS

By G. E. Cottral[1]

A. There are three recognized clinical forms of foot-and-mouth disease (FMD):

1. Acute—classical signs and lesions.
2. Subacute—mild or delayed signs and lesions.
3. Occult—carrier without signs or lesions.

B. There are at least 10 recognized sources of FMD infection:

1. Direct contact with infected animals.
2. Aerosols from remote infected animals.
3. Contact with contaminated objects.
4. Eating contaminated garbage: meat, milk, blood, glands, bones, hides.
5. People: expiration, hands, footwear, etc.
6. Artificial insemination: infected semen.
7. Contaminated biologics.
8. Vectors: non-host animals and birds.
9. Arthropods and parasites.
10. Sabotage.

C. FMDV exit routes from an infected animal: aerosol, nasal discharge, saliva, lesion debris, tears, blood, semen, urine, milk, foot lesions, aborted fetus, vaginal discharge, and feces.

D. FMDV entry routes into a susceptible animal: inhalation, mouth, eyes, feet, teats, wounds, bites, artificial insemination, biologics, and instruments.

E. Pathogenesis of FMDV:

1. Inhalation of virus.
2. Infection of cells in nasal chamber, pharynx, and esophagus.
3. Replication of virus and spread to adjacent cells.
4. Escape of virus to blood and lymph vessels.
5. Infection of lymph nodes and other glands.
6. Infection of cells of the oral cavity, feet, rumen, heart, and skin.

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[1] Plum Island Animal Disease Laboratory.

7. Beginning of fever.
8. Appearance of vesicles of oral cavity, feet, rumen.
9. Appearance of salivation, nasal discharge, lameness.
10. Rupture of vesicles and increased clinical signs.
11. End of fever.
12. End of viremia and start of detectable antibody production.
13. Decline of virus titers in various tissues and fluids.
14. Healing of lesions and resumption of eating.
15. Gradual disappearance of virus in most tissues and fluids.
16. Healing completed, but continued residence of virus in throat area with slow replication, resulting in carrier state.

F. Aftermath of FMD infection:

1. Heart damage: unthrifty.
2. Glandular disorders: pituitary—panting.
3. Lameness: hoof deformation.
4. Breeding problems: irregular estrus, abortion.
5. Mastitis: poor milkers.
6. Chronic secondary infections.

G. Normal-appearing spreaders of FMD:

1. Preclinical stage: danger from aerosols, semen, milk, glands and bones.
2. Convalescent stage: danger from aerosols to about 8th day, and from semen, milk, glands and bones.
3. Long-term carrier stage: potential danger from virus in throat and possibly elsewhere.

H. Duration of the carrier state:

1. Cattle: over two years.
2. Sheep: as long as 13 months, most end by 6 months.
3. Goats: most end by 6 months.
4. Pigs: only to end of clinical stage—5 to 7 days.

I. Types of carriers of FMDV (without clinical signs or lesions):

1. Immune carrier: antibodies present.
   a. Convalescent from infection.
   b. Vaccinated—then infected.
   c. Serum protected—then infected.
2. Non-immune carrier: antibodies absent.
3. Latent carrier: antibodies absent.
   a. Virus not readily isolated.
   b. Genomic masking theory: RNA of FMDV in protein coat of enterovirus.

J. In the study of carriers, oesophageal-pharyngeal (OP) fluid is collected for virus isolation from the throat. A cup-probang is passed into oesophagus 2 or 3 times and each time it is moved up to pharynx 3 or 4 times before

removal. The object is to obtain cells from pharynx and esophagus; saliva *per se* is not wanted except as a vehicle. The fluid is diluted equal parts with tissue culture supporting fluid and is shaken to break up mucous. The fluid is then homogenized with a fluorocarbon, centrifuged and the supernatant fluid is withdrawn. This treatment removes feed debris, bacteria, fungi, and helps break up antigen-antibody union. The fluid may then be inoculated into the tongue epithelium of susceptible cattle or into tissue cultures. Either the plaque assay or cytopathic effect (CPE) assay techniques may be used in tissue culture. If virus is present in sample the tissue cultures will show progressive signs of infection either plaques or CPE. In cattle, tongue lesions will appear in about 24 hours and the disease will progress to a recognizable clinical stage.

K. Serum is also collected from suspected carriers for serological studies. Virus neutralization tests are set up with known FMD virus and the suspected serums and both positive and negative controls, using various dilutions of either the virus or the serums. The serum-virus mixtures are incubated at 37° C. for an hour and then are inoculated into suckling mice or tissue cultures. One litter of mice is used for each serum-virus dilution mixture. If antibodies are present in sufficient quantity in the serum, the virus will be neutralized and will not cause paralysis and death of the mice—a positive result. If the mice die as in the controls, this could be a negative result. The presence or absence of plaques in tissue cultures may be utilized in a similar manner for determining the presence of antibodies in the serum.

PAPER NO. 5—PIADL RESEARCH AND DIAGNOSTIC SERVICES

By J. J. Callis

Inasmuch as few of you present have ever been to Plum Island, I thought I would begin my presentation telling you about how the need for the laboratory was identified, where it is located, and finally what we do there.

The laboratory was established for research on the so-called exotic or foreign diseases of livestock in order to strengthen protection against these diseases and to develop additional information about them. Although FMD has not occurred in the U.S. since 1929, it has threatened directly in the last 2 decades; from Mexico in 1946-1955, and from Canada in 1952. The disease is regarded as the number one enemy of our livestock. Soon after the outbreak of FMD in Mexico in 1946, two U.S. advisory committees were appointed by the Secretary, one comprised of representatives of the livestock industry, the other of scientists. Both groups recommended cooperation with laboratories in foreign countries and establishment of a laboratory in the U.S. for research on FMD and other foreign animal diseases. Public Law 496 authorized establishment of the laboratory and the law read basically like this, "The Secretary of Agriculture is authorized to establish laboratories for research and study in the United States or elsewhere of foot-and-mouth disease and other animal diseases which constitute a threat to the livestock industry of the United States providing the laboratory is established on a coastal island separated by deep navigable waters."

While P.L. 496 was passed in 1948, funds for construction of the laboratory were not appropriated until 1952, very soon after the occurrence of FMD in Canada. During the Canadian outbreak we read accounts of the disease that went something like this which is copied from the April 1952 issue of the Farm Journal:

> "On Monday, November 26, Leonard T. Waas, a farmer 25 miles from Regina, noticed that some of his 39 cattle were off feed and stiff. On Friday he called a district veterinarian. The vet happened to be sick in a hospital, and all he could do was to advise Waas to drench the animals.

Two of Waas' neighbors, D. A. Smith and Liddle Wood, came over to help. They didn't know that they were working with a dangerous disease. By Monday, December 3, the cattle were worse; that was the first day the Federal veterinarians saw the animals. They ran tests and called the disease stomatitis.

Wood went home from the Waas place and milked his cows without washing his hands. Five days later his cows had the disease.

Smith went home and mixed feed for his calves without washing his hands. Three days later his cattle had it.

In the meantime Waas shipped six animals to the Burns Packing Plant. Infection broke out in the feed lot connected with the slaughter plant.

Somehow the infection got into the 10 bulls that the Government keeps in Regina for lending to breeding clubs. E. H. Wobeser told me that he took one of his cows to the bull barn, and a few days later had the disease in his herd.

Another farmer's trouble started a few days after a veterinarian had taken care of one of his cows that had calved.

A dairy farmer with some mild "trouble"—so mild he didn't report it—sold two calves to a farmer 50 miles away. This farm became infected, as did a neighboring place.

While all this was going on, the veterinarians weren't sure what they had. A few thought it might be foot-and-mouth; others didn't agree.

Finally, on February 16, samples were sent to the government laboratory at Hull, Quebec. Dr. M. S. Shahan of the USDA was called in for consultation. He saw the Hull tests and those at Regina and agreed that it was foot-and-mouth all right. This was 13 weeks after the first cases started!

From all of the evidence the Canadian authorities were able to piece together, the disease got into Canada by way of an immigrant who came to work on Mr. Waas' farm 11 days after having left Germany where he worked on a farm where foot-and-mouth disease existed. The virus hitch-hiked on his clothing or was contained in a piece of sausage which he carried in his farm smock."

It is generally accepted that the Canadian outbreak provided the stimulus necessary for Congress to appropriate funds for the laboratory.

After the funds were appropriated Plum Island, situated about 2 miles from the eastern end of the North Fork of Long Island, was selected as the site for the laboratory. For almost 60 years the island was the site of military installations which included a research laboratory suitable for biological research. In 1954 the island became the property of USDA. It is 3 miles long, and a mile wide at its widest point and is about 800 acres in size.

Some modifications were made to the small laboratory building on the island left there by Department of Defense and it was suitable for work with FMD. The availability of this building allowed establishment of limited diagnostic capabilities for FMD in 1955, one year before the new laboratory building was finished and three years before it was placed in full operation.

Because FMD is nonexistent in North America, special precautions are taken to prevent escape of the virus and consequent infection of our livestock. Location of the laboratory on an island is the first safeguard. Traffic to the island is limited to a few government owned vehicles needed for delivery of supplies, including experimental animals and feed. Only persons having official business are permitted entry on the island. Vehicles and personnel travel to and from the island by one of three boats. Cargo from the few vehicles permitted to go to the island is transferred in the harbor area to other vehicles which are confined to the island proper.

All research involving infectious agents is conducted within the tight confines of two buildings. One is utilized chiefly for diagnostic investigations, including research on diagnostic procedures. In the other are conducted biochemical, microbiological, cytological and immunological investigations.

Both buildings are enclosed within two chain-link fences. The inner fence surmounts a concrete wall and that extends into the ground to prevent entry of burrowing animals. The buildings are tightly constructed, without any open windows and entry is limited to specifically authorized personnel.

Air is filtered before entering the building and it is all filtered before being exhausted from the building. Air pressures are progressively lessened from the outside to the inside.

All fluids which include manure from animals that are fed chopped feeds is decontaminated with heat before it is discharged in the sea surrounding the island.

Solid wastes from the buildings, such as animal carcasses and used laboratory supplies, are incinerated in units connected directly to the building.

All personnel entering the buildings are required to disrobe before entering contaminated areas where they don laboratory clothing. Before they exit, all such clothing is discarded and each person is required to shower completely before donning his street clothing.

All laboratory personnel as well as visitors are required to refrain from contacting animals of susceptible species or actual premises where they are held for 7 days following their visit.

Only when absolutely necessary is it permissible to remove equipment from the laboratories or the island and only then after the article has been decontaminated. These and many other safeguards and operating procedures are followed so as to contain the disease agents with which we work. Safety is uppermost in our minds in everything we do. The safety regulations were designed to protect the U.S. livestock industry from the disease agents with which we work. The two main buildings on Plum Island which were specifically designed for work with highly communicable diseases, are considered to be among the safest in the world for work on animal viruses.

Of the laboratory's 330 employees, approximately 10 percent are members of the research, diagnostic and administrative staffs. Science disciplines represented in this group include veterinary science, virology, bacteriology, pathology, chemistry and physics. The professional staff is supported by technicians, engineers, animal caretakers, maintenance crew, craftsmen, marine personnel, library and clerical staff, safety and security staff including guards and firemen.

The program of the laboratory is divided into service and research functions. While initially not much service work was conducted last year it is estimated that 30 percent of the total effort of the laboratory was devoted to service functions. To a large extent these functions are a natural outgrowth of the research competency which the laboratory has developed since its founding.

To date, diagnostic competency has been completed for 18 foreign animal diseases and of those not yet studied, six are scheduled for early review. One of the difficulties of accurately identifying a disease has been the lack of tests to distinguish it from another disease which may present similar symptoms. The importance of diagnostic capability and the resultant consequences when that capability does not exist, has been demonstrated in a number of cases in the U.S. Bluetongue of sheep and Newcastle disease of poultry are typical examples. Because few veterinarians were familiar with bluetongue of sheep an outbreak around 1950 went undiagnosed and became widely spread through the southwest before it was correctly diagnosed in 1952. Newcastle disease of poultry reached the U.S. about 1940 but because of the atypical nature of the disease in California it was not definitely diagnosed until 1944. By 1947 it spread to virtually all of the states.

As a result of the competency of the staff in diagnosing exotic animal diseases we are called upon increasingly to perform emergency diagnostic services for State and Federal veterinarians who have encountered a disease with which they are not familiar. Such investigations are always handled promptly for we take the view if it was not an emergency it would not be sent to us. If the diagnosis reveals that the suspected animal disease is an exotic one, further follow-up service may include field surveillance of the herd or herds in the area.

Another and increasingly important service function of PIADL is that of training offered for field veterinarians of the USDA Animal Health Division. Two, one-week long, training sessions were given this year to about 25 veterinarians in the recognition of foreign animal diseases. As a result of occurrence of African swine fever in Cuba during May of this year three training programs were given to USDA, State and university personnel in this country and to staff from Mexico and Central America in the recognition and diagnosis of this disease.

As I am sure some of you recognize there is an increasing demand in the U.S. for semen from breeds of cattle that do not exist here. The purposes of these importations is to allow hybridization by crossing the European breeds with our beef stocks.

From time to time we are also called upon to conduct specialized studies with particular reference to a given imported animal product to determine whether it is safe to import it or not. The laboratory staff also serves in an advisory capacity to other USDA groups on questions pertaining to foreign animal diseases.

The research programs at PIADL have roots that undoubtedly may be traced back to the nine FMD outbreaks we have had in this country and to the one in Mexico and Canada. For in addition to serving the livestock industry in operating a diagnostic laboratory for exotic animal diseases our other important function is to conduct research on these diseases so that we know better how to keep them out and also when they do enter, how best to get rid of them.

Research activity at PIADL approximates 70 percent of the total staff effort. Since establishment of the laboratory 17 years ago the FMD projects have outnumbered the others. Current emphasis on the basis of total scientific man years devoted to a particular disease is FMD 54 percent, ASF 11 percent, CBPP 5 percent, and the remainder of the effort is related to diagnosis.

Specific disease related research is organized more or less along four science discipline lines, microbiological, cytological, biochemical and physical, and immunological. This organizational method gives the advantage of an interdisciplinary approach toward the research problems associated with any one particular disease.

Microbiological investigations deal essentially with the role of the carrier, that is, the host animal in the spread of the virus, the susceptibility of various species of animals and the survival time of virus in meat and other animal products. Much work has been done on the carrier animal as Dr. Cottral will explain to you later.

In cytological investigations we are studying the relationship of virus and cells trying to develop information that will contribute to ways to produce large quantities of virus and ways to alter FMDV to the extent that it is suitable as a vaccine.

In biochemical and physical investigations we are studying the chemical and physical properties of virus and Dr. Bachrach will go into considerable detail about this later this morning. Here I might say that our almost two decades of research on the chemistry and physics of FMDV has yielded a wealth of information so that we probably know more about FMDV than is currently known about any other animal virus.

In immunological investigations the work is aimed at developing better FMD vaccines, primarily those that afford a better immunity over a longer period of time. With some diseases, much success has been achieved, with others like ASF we are a long ways away. As information is developed on the diseases, carrier states and the properties of the virus elucidated, the probabilities of our success are increased. Other work in immunology relates to study of the immunology of FMD and immune reactions.

An evaluation of the impact of the research programs at PIADL on the status of foreign animal diseases in the U.S. cannot logically be separated from the efforts of regulatory and control agencies. The two efforts complement each other and are fundamental components of any nation's plan to hold down the incidence of a given disease or to prevent it from entering. The real progress of a disease research program is the weapons it provides in the form of added knowledge about causes and control. In that respect the PIADL program has been productive because we know more about many exotic diseases than was known before. We might even speculate that without this knowledge which was applied just as soon as it was developed we might have had more diseases enter than has been the case. The activities of the PIADL program have reached out into many corners of the world, not only in cooperative investigations, but in actual application of knowledge in diagnostic, educational and training programs. Wherever our efforts help in controlling a disease, the chances of that disease getting into the U.S. are lessened. As information about these diseases increases, ways must be found to further diminish the incidence through better control measures.

PAPER NO. 6—HISTORY OF FOOT-AND-MOUTH DISEASE IN THE UNITED STATES OF AMERICA

By Norvan L. Meyer

If a person predicts a calamity and that calamity fails to materialize, the predictor soon finds himself in the position of the little boy who yelled wolf too often. When the wolf finally comes, nobody will listen. It has now been more than 40 years since the last outbreak of foot-and-mouth disease (FMD) in the United States of America (U.S.A.). Many of our protective mechanisms have improved. So why worry!! Not since the turn of the century has the disease been introduced through importation of infected animals. Since 1900, at least once and probably twice the disease was introduced into the United States of America through contaminated vaccinia virus—smallpox vaccine produced in cattle—and at least two outbreaks resulted from feeding swine raw garbage from ships which stocked meats from FMD-infected countries. Controls have now been set up to prevent importations of the disease by susceptible animals and animal products.

Modern methods of fast worldwide transportation are changing this picture. Nearly all live animals and poultry imported into the United States—except zoo animals and livestock and poultry from Canada and Mexico—come by air. If the barrier provided by the Darien section of Panama disappears, the threat of introduction will be magnified and Panama, Central America, Mexico, the United States, and Canada will be in real danger from FMD.

While the threat of FMD is increasing, the need for additional animal protein is also increasing.

According to James A. Oliver, Coordinator of Scientific Programs for The American Museum of Natural History, each week at least 10,000 human beings die of starvation. Moreover, of the 3½ billion people on the earth today, two-thirds are undernourished by medical standards, and the situation will probably get worse.

During the next one minute, about 234 babies will be born on earth. At the end of an hour, more than 14,000. Discounting the some 6,000 deaths that will occur, the newborns will have brought about a net increase of 7,900 individuals in just 60 minutes. By this time tomorrow, the net population of the world will have increased by a mass of people approaching the population of cities such as Managua, Nicaragua, or San Jose, Costa Rica, or Ciudad Juarez, Mexico, or San Salvador, El Salvador, or Panama City, Panama, or Salt Lake City, Utah—in other words about 190,000 individuals. By the end of this century, it is estimated that the world's population will double. The estimated increase for the United States is 100 million. Based on present growth rate figures—and in the past actual growth has always outstripped the estimates—within our lifetime or at least the lifetime of our children, the world's population will probably double, and the desire for animal protein will increase even more rapidly.

Foot-and-mouth disease is the most explosively destructive of all livestock diseases. Destructive not because of death loss alone, but primarily because of the ability of the disease to spread like wildfire and infect large populations of cloven-footed animals—domestic and wild. Cattle, sheep, swine, and goats, as well as at least 30 species of wild animals, are all susceptible. The presence of this disease is a major factor in limiting world trade in livestock, meat, and other animal products. FMD-free countries should continue to do every thing possible to prevent foot-and-mouth disease from gaining entrance, and should continue to develop plans to eradicate the disease quickly if it should appear.

Many people think of foot-and-mouth disease as a simple, comparatively uncomplicated disease—like blackleg or anthrax. *IT IS NOT*!! There are seven completely distinct types of the virus. Each is immunologically distinct. In other words, immunity to one type does not confer immunity to the other six types. In addition, there are more than 50 subtypes of virus which cause foot-and-mouth disease. For instance, there are at least 24 subtypes of Type A, with a couple of new ones suspected but not yet confirmed at the World Reference Center in Pirbright, England. Subtypes are each somewhat similar but each just a little different.

Because of the many types and subtypes of virus, control of foot-and-mouth disease by vaccination is complicated and difficult to accomplish. For instance, in order to provide complete protection against foot-and-mouth disease, it is theoretically necessary to use more than 50 vaccines—one for each subtype.

During the 1967-68 outbreak in England, FMD virus was isolated from milk in bulk tanks used for hauling milk to market even though none of the cows supplying the milk showed signs of FMD. It is now known that after exposure a milk cow may excrete virus several days before she begins to show lesions.

Advance in technology also creates problems. In order to get better tasting and better quality milk, pasteurization techniques have changed. The old method of pasteurization—about 145° F. for 30 minutes—inactivates all or nearly all the virus in milk. However, FMD virus may survive when the milk is pasteurized using the flash method—about 162°F. for 15 seconds.

There were three outbreaks of foot-and-mouth disease in this country prior to the turn of the century. Each of these outbreaks is believed to have been caused by importation of infected or carrier animals. The first recorded introduction of the disease was found in the United States in 1870. The disease was brought into this country by cattle shipped from an English port in August 1870. The cattle showed signs of the disease at sea, passed through the worst stages on the ocean but conveyed the infection to the stock among which they were placed on their arrival in Canada. The existence of FMD in the State of New York was reported in September 1870—about the time of the State Agricultural Show. It is believed the disease was brought in by Canadian cattle exhibited at the show. Other reports indicate the disease may also have been brought to the Albany Stockyards by Canadian cattle. From there it spread to the States of Connecticut, Massachusetts, and New Hampshire. The following year the disease still lingered at several points in the northeastern part of our country but it soon died out. The lack of transportation facilities—there were no railroads, no highways, and no steamship transportation facilities in England—probably assisted in eliminating this outbreak without the use of formal eradication procedures.

Foot-and-mouth disease was again brought into the country in 1881 by the importation of 2 bulls and 8 heifers. They came into the port of New York from England. The animals were quarantined in that city for a period of 90 days. At that time, quarantine laws and regulations were administered by the Treasury Department. Many felt that the Treasury Department did not have sufficient knowledge of animal diseases and that control of import of livestock should be placed under the supervision and direction of competent veterinarians. As a result of the outbreak and accompanying outcries from livestock producers in the United States, a Treasury Cattle Commission was formed and funds were appropriated in 1883 for the purpose of establishing quarantine stations for livestock along the Atlantic Coast. These quarantine stations were to be used for the detention of imported cattle. An order was issued by the Secretary of Treasury on July 30, 1883, requiring that all cattle from any part of the world except North and South America be held in quarantine at a port of entry for a period of 90 days.

In 1884, there was a small outbreak at Portland, Maine, caused by import cattle and the disease spread to a few herds outside the quarantine station. Since there was only a small number of animals affected and the disease covered only a small area, it was brought under control without resorting to slaughter.

In each of these early outbreaks, FMD was introduced with imported animals. Since the development of a stringent system of inspection and quarantine of imported livestock, no instance of that kind has occurred. On

subsequent occasions, the infection has evidently been brought in with contaminated products or materials and not by live animals.

In 1902, an outbreak occurred near Chelsea, Massachusetts. At first, the outbreak was believed to have been introduced by foot-and-mouth disease virus-contaminated materials from ships from foreign countries. Later, evidence made it quite clear that contaminated smallpox vaccine from Japan was to blame. The disease started to spread and four States—Massachusetts, Vermont, New Hampshire, and Rhode Island—were infected before the outbreak could be stopped. All infected herds were slaughtered and the infected premises were cleaned and disinfected. The United States Department of Agriculture Yearbook for 1902 contained a report on the outbreak. The report contained a number of very interesting observations. For instance: the report says the disease was easily carried from stable to stable by persons, and it was necessary to take precautions to prevent its spread in this manner by inspectors who must necessarily visit the herds. This observation resulted in inspectors being instructed to wear rubber protective clothing when inspecting animals and to disinfect them when leaving the premises.

It was noted that FMD was a much feared malady and for the first time it was acknowledged to be more important and more dangerous than contagious bovine pleuropneumonia.

In 1908, another outbreak occurred. The disease spread from the Detroit Stockyards into the State of Michigan and later into Pennsylvania, New York, and Maryland. The same lot of vaccinia virus imported from Japan in 1902 proved to be the source of infection. Vaccinia virus is produced in cattle and is used for smallpox vaccine production. As a result, manufacturers of vaccine for human use were required to initiate procedures to test vaccine for the presence of foot-and-mouth disease virus. The Federal Government spent about $300,000 on the control program and the States involved spent about $113,000. The 3,636 animals destroyed had an appraised value of $90,033.18.

The largest United States outbreak occurred in 1914. At least 22 States and the District of Columbia were infected. The infection spread over wide areas in the Northcentral and Northeastern parts of the country and in places penetrated to the far Northwest. The outbreak started in the vicinity of Niles, Michigan, in October 1914 where it had apparently been underway since the previous August. Early cases were apparently quite mild and for that reason the disease was not immediately detected thus permitting the disease to spread to a large number of herds and animals. The stockyards at Chicago became involved and from there infection was disseminated to other stockyards and to many parts of the country. The source was believed to be imported hides although positive proof was lacking.

A total of 3,556 herds valued at more than $5,800,000 were slaughtered. In 1924, two totally unrelated outbreaks occurred—one in California and one in Texas. In California, the source was determined to be raw garbage from ships returning from foreign countries. In the course of the eradication program, foot-and-mouth disease was found in deer in the Stanislaus National Forest. More than 22,000 were slaughtered. Finding the disease in wild animals presented a new and serious problem in eradication. The problem was discovered when a local cattleman found dead deer in the Stanislaus National Forest. The cattleman became suspicious because of lesions on the feet and mouth. It was decided to depopulate the infected range. It was also decided that strychnine poisoning was the best method of depopulating the deer range, especially where shooting might scatter exposed and infected deer. Although not every deer on the range was eliminated, eradication procedures were continued until several months had passed without finding any infection in deer that were being slaughtered.

A total of 941 herds of domestic animals with a total appraised value of more than $4,280,000 were slaughtered.

The origin of the 1924 Texas outbreak was never definitely established. However, stevedores and sailors from foreign ships docking in the Galveston-Houston area often bathed and washed their clothes in the water tank in the pasture where the disease was first discovered. A member of our staff recently reviewed the records of that outbreak

and discovered that the same pasture contained seven Zebu bulls which had come from Brazil by way of Mexico. We now know that bovine animals often remain carriers for months and years after exposure. Possibly the bulls were the source of infection.

Foot-and-mouth disease reoccurred on the same Texas premises on July 26, 1925, about 6 months after removing the last quarantine from the 1924 outbreak.

The last United States outbreak occurred in 1929 in California. The origin of the outbreak was not determined.

There are two factors which place foot-and-mouth disease at the top of the list of the livestock diseases most feared in this country:

1. FMD is extremely contagious, probably the most contagious animal infection; and
2. The disease is quite similar to a number of other conditions commonly present in this country. Early cases might be mistakenly identified as a common domestic disease.

One such disease is vesicular stomatitis, which occurs nearly every year in the United States and in Mexico, Central America, Panama, and South America. The signs and symptoms presented by VS are identical to those of FMD. Not even our most expert diagnostician can distinguish between the two by clinical examination alone.

Foot-and-mouth disease lesions usually occur in the mouth and on the feet. Textbooks describe the lesions as vesicles or blisters. Often, they look like simple erosions.

Most people think that if FMD occurs they will see a big blister or a giant sore on the tongue; however, FMD mouth lesions may be very mild in the individual animal.

Vesicular exanthema, a disease of swine, is also indistinguishable from foot-and-mouth disease. Formerly confined to California, a widespread U.S. outbreak occurred starting in 1952. Forty-two states and the District of Columbia were affected before the outbreak was brought under control. In the field, typical vesicles are rarely seen. The presence of a vesicle would only indicate a vesicular disease: Vesicular exanthema, vesicular stomatitis, or foot-and-mouth disease. Laboratory tests would be required to determine which disease is involved.

There are many animal diseases which present clinical signs similar to FMD. All suspicious signs should be reported for veterinary diagnosis. Without such precautions FMD could become established and cause great destruction to our livestock industries. We are vitally concerned about FMD and what it could do to the livestock industry in the FMD-free countries of Panama, Central America, Mexico, and the United States. I believe the opening of the highway through the Darien Gap will greatly magnify this threat. We also believe it is technically possible to negate this increased threat by setting up proper FMD prevention procedures, but we must act now. Plans should be set up as the highway is being built. When the highway is finished, it may be too late.

PAPER NO. 7--PROGRAMS TO PREVENT ENTRY OF FOOT-AND-MOUTH DISEASE INTO THE UNITED STATES

By Dr. Claude A. Smith

Probably the single most important factor which permits this country to excel in livestock production has been the successful animal disease prevention program for keeping out livestock diseases of foreign origin. This does not mean to imply that our efforts have been 100 percent successful for all diseases, but it has been effective for those considered most devastating to animal production. For example, the United States has remained free of foot-and-mouth disease for over 42 years. During the last 20-year period, both our closest neighbors (Mexico and Canada) were infected with foot-and-mouth disease. Many other countries that once considered themselves free of this disease also became infected and many of these are still declared infected by this Department. (Venezuela, Columbia, South Africa, Great Britain, Martinique, Curacao, Guadeloupe, Sweden, and Cuba became infected and remain so today.) Other countries became infected during this 20-year period of time but have successfully eradicated the disease since (Norway, Channel Islands, Eire, Northern Ireland, Canada, and Mexico).

United States' efforts to protect against the introduction and spread of foreign animal diseases began over a century ago. Since that time a number of laws have been passed and amended to better provide for the protection of the United States against animal disease introduction. Until the advent of modern transportation, the travel time took so long that animals in the incubative stages would show evidence of disease by the time they were offered for importation into the United States. More modern and speedier ocean transports shortened the travel period of time. Then in rapid succession came propeller aircraft and jet aircraft to reduce travel time to a few hours between any two points in the world. Successful techniques for loading animals aboard aircraft caused a shift in transport so that now many of the animals, if permitted, are transported by aircraft from one overseas country to another.

With the advent of containerized ocean shipping and the superjet, a new concept of international commerce is being developed that vastly increases the potential danger of animal disease transmission from one country to another. There are now ships afloat that handle nothing but containerized cargo. These containers are used for livestock as well as for meat, other animal products, and related materials, and other nonagricultural commodities as well. These containers become the trailer portion of a tractor-trailer highway rig when offloaded from the transoceanic carrier and are of four general types—open, enclosed, insulated or refrigerated. The refrigerated containers are all equipped to operate on gasoline, bottle gas, and electricity. The containers for animals have provisions for feed and water.

These containers are loaded with commodities in the interior of the origin country. They are then moved overland to the port of embarkation where they are placed aboard the ocean vessel or plane. Upon arrival at the destination country, the containers are removed and transported to destination within the interior of the receiving country where the commodities are then unloaded. This procedure makes regulatory control over sanitation prior to unloading an almost impossible task. The concept of loading the container at origin and unloading at final destination makes inspection at peripheral ports of entry impracticable, and sanitary control at the time of unloading cannot be assured because of the many such locations involved in the destination country.

Thus, it becomes increasingly more difficult to protect the United States against animal disease introduction by sanitary control over international shipment of animals, meat, animal byproducts, hay, straw, and related

materials, because the containers themselves may have been contaminated through prior use, and the unloading of presumably innocuous cargo can cause spillage of debris in the country of destination from previously transported cargo from some other country. For example, in Liverpool, England, an enclosed ocean container awaiting delivery to a prospective exporter was found to contain considerable wool and other debris presumably from previously transported wool fleeces. It would be relatively easy for FMD virus, for example, to be carried by such animal products swept out of a container in the United States after transporting fence wire to the United States. There are now ocean ships that transport one thousand or more of these containers, and the trend is developing for the use of similar containers in jet aircraft. U.S. Department of Agriculture representatives are working with the Department of Transportation and Bureau of Customs, as well as other Government agencies, to consider applicable regulatory measures, but the task is most difficult.

Protection of a country against foreign animal diseases is basically by two methods. One is by an outright prohibition, and the other is by the establishment of import requirements with respect to the various animals or commodities involved. The purpose is to prevent the international shipment of diseases, animals, or animal products from diseased animals or products contaminated with animal diseases. This in itself would not be too difficult a task were it not for animals that were in the incubative stages of the disease or carrier animals and products derived from infected animals or carrier animals or contaminated with animal disease-causing agents.

In the case of the International shipment of animals, efforts to eliminate the "questionable" animal begins with the salaried veterinary authority of the national government of the country of origin. He may be required to certify concerning the disease status in the area of origin; the health status of the premises and herd of origin; assurance that the animals for shipment have been kept free of disease exposure; certification that the animals were negative to various tests; documentation regarding embarkation quarantine, and statements about required precautionary treatments.

Further control may involve the issuance of a prior permit which specifies that no animals other than those qualifying for shipment shall be permitted aboard the carrier; lists any permitted stops en route; designates the port of entry into the United States; and specifies the origin of the hay, feed, and bedding used en route. At the port of arrival in the United States, USDA veterinarians inspect the animals for evidence of disease, require the cleaning and disinfection of the equipment used to handle the animals, supervise a period of quarantine at the port of arrival, complete various tests and precautionary treatments during quarantine, and in some instances exercise destination control over animals released from the port of entry quarantine station.

Most countries of the world with which the United States does business have diseases of livestock that do not exist in the United States. With respect to import animals, there is one major difference as compared to meat and related materials. This is the fact that there are 85 specific Customs ports of entry designated for the importation of animals (54 along the Canadian border, 16 ocean ports, and 15 along the Mexican border). All animals offered for entry into the United States must be presented at one of these designated ports of entry. In contrast, there are nearly 300 Customs ports of entry through which meat, animal products, and related materials may be legally offered for entry into the United States.

Over the last 11 years, an average of 1 million animals have been imported into the United States yearly. A great percentage of these come from Canada where the animal health situation compares favorable with that of the United States. The most potential threat involves activities along the vast 3,000-mile land border if Canada should be so unfortunate as to again become infected with FMD or other similar livestock disease.

The problem is similar with Mexico, but there are even more complicating factors. In general, the animal disease control programs are not as fully developed in Mexico as in the United States and the 2,000-mile border between our two countries offers little deterrent in some areas to stray animals or the illegal movement of animals. All import animals from Mexico are required to be given a precautionary dipping at the port of entry because cattle fever ticks as well as scabies exist in Mexico.

The import requirements for any animal for any country vary depending upon the kind of animal involved and the purpose for which it is imported into the United States. As with all import requirements, the attempt is made to make certain that they are as stringent as necessary to protect livestock in the United States against disease, but on the other hand, to make certain that the restrictions are no more stringent than is absolutely necessary to provide such protection.

The Department is concerned with commercial shipments of animal products that might transmit animal diseases of foreign origin. These include commodities such as bones, horns, hooves, wool, hair, bristles, hides, skins, blood meal, glands, etc. These products are used for various purposes ranging from crushed bone in the hardening of steel to glandular products in the production of pharmaceuticals. In general, such products are handled under supervision at the port of entry so that the equipment used and area involved can be properly cleaned and disinfected; the commodities are permitted to go forward under Government seal to specifically approved establishments (or to specifically approved bonded warehouses for temporary storage) for final processing at destination in a manner acceptable to the Department.

Commercial shipments of meats into the United States may originate in any one of over 1,000 establishments in 38 countries approved by the Consumer and Marketing Service (C & MS) of USDA. Of these establishments, 439 are in 23 countries which are on the Department's list of those which are declared infected with FMD or rinderpest. From this number, five countries are the source of uncanned, cooked meat that may be imported into the United States for consignment to specifically approved plants for further heat processing (usually into sterilized canned products). Three countries (Argentina, Brazil, and—most recently—Columbia) are the source of uncanned, cooked, frozen beef processed in C&MS-approved establishments which have also been approved by ARS as having cooking equipment, processing procedures, and separate handling personnel, so that the finished product need not be consigned to an approved plant for further heat treatment in the United States before release.

Another group of countries is the source of perishable canned hams that have been heated to a minimum temperature similar to pasteurization but have not been sterilized. This results in a canned product that is not shelf stable without refrigeration. Release in the United States is based upon accompanying documentation and statistical sampling in the United States to determine that the product is as represented. Finally, another group of countries is the source of dried and cured beef and sausages. In this category, dried pork products are not permitted from countries such as Italy where African swine fever is known to exist because the drying process is less effective for destruction of African swine fever than it is against FMD virus.

Garbage aboard ships and airplanes is a continuing threat to possible disease introduction. This is particularly ture with respect to seastores or airplane stores where these products have been acquired in countries where devastating animal diseases exist. This is the reason for the requirement that garbage is not permitted to be removed from such carriers except under supervision for incineration or other appropriate disposal.

Passengers arriving in the United States from foreign countries are almost constantly bringing in meat and other animal products from foreign countries. The increasing numbers of such international travelers has placed a great deal of pressure on the border inspection agencies (primarily Customs) and their ability to intercept prohibited or restricted animal products.

The Bureau of Customs has experimented with various types of systems concerned with the inspection of incoming travelers. One was the "accelerated inspection system" (one-stop) which was tried but discarded by Customs last year. This system had an effectiveness of about 45 to 55 percent for the interception of agricultural products. The current system being tried is called a "selective inspection system" (SIS) where Customs personnel make the determination about the need for inspecting the baggage of incoming passengers. Data is not yet available as to the effectiveness of this system. However, during fiscal year 1971, there were 75,858 pounds of meat and animal products seized in baggage of passengers from incoming airplanes and ocean vessels.

The U.S. Department of Agriculture is working with Customs in attempting to warn travelers about prohibited and restricted agricultural products. USDA has suggested that the Customs Declaration be amended so that passengers must make a positive statement as to whether they are or are not carrying restricted or prohibited agricultural products. It is difficult for Customs inspectors to always ask travelers questions about whether or not they have been in rural areas or on farms that would then trigger a closer inspection of their accompanying baggage. Too often when extended interrogation is used, the backlog of passengers grows to alarming numbers; and it is not then uncommon for the Customs supervisor to invoke "Rule 21" which, in effect, permits backlogged passengers to proceed without further inspection in order to clear the area for other arriving passengers.

Customs and airlines have also been reluctant to allow USDA to install signs warning passengers of agricultural requirements because this detracts from other airline and Customs messages.

Other restricted or prohibited products gain entry into the country through false labeling, improper manifests, and, of course, in packaged mail. With our new postal system, there remains the need for determining the effectiveness of cooperation between that new postal service and USDA representatives to better protect against animal disease introduction. The general practice is to screen out no more than 30 percent of likely packages and open half these for closer scrutiny.

Control over animal semen importations is a necessary regulatory procedure. The need to acquire additional bloodlines and other animals of "desirable genetic characteristics" has caused an upsurge in interest of semen importations. While necessary testing techniques have yet to be worked out for many species of livestock, they have been developed for bull semen. Breeds of interest include Charolais, Simmental, Limousin, Blonde d'Aquitanne, Fleckvieh, Maine Anjou, Murray Grey, Pie Rouge, Chianina, Romagnola, and Marchigianu.

Control is exercised over animals such as horses even though they do not become infected with foot-and-mouth disease. Since they are likely to be kept around animals susceptible to the disease, horses are required to have their feet picked clean and disinfected and their hair coat sponged with a weak acetic acid solution if they originate from countries where foot-and-mouth disease exists.

Zoological animals from foot-and-mouth disease or rinderpest-infected countries are specifically covered by a provision of the prohibitory statute. They are required to undergo minimum 60-day embarkation quarantine in USDA-approved facilities in the country of origin, nonstop transportation to New York as the only port of entry where such animals may enter the United States, minimum quarantine there of 30 days during which time various tests may be completed, and consignment to specifically USDA-approved zoological parks where they must remain under permanent post-entry control.

The Department relies heavily on the Veterinary Sciences Research Division of the Agricultural Research Service for diagnostic capability with respect to animal diseases, research concerning many of the foreign animal diseases, and for consultation in arriving at adequate restrictions that will provide necessary protection to the U.S. animal population. Perhaps the biggest deterrent to continued success is the complacency that develops because the United States has had more than four decades of freedom from devastating livestock maladies such as foot-and-mouth disease. Constant efforts must be directed toward the continued commitment that such exotic diseases shall not ever be permitted to enter and spread within our country.

PAPER NO.8—EMERGENCY DISEASE ERADICATION ORGANIZATION—OLD AND NEW

By R. E. Omohundro[1]

For the next couple of days you are going to be asked to concentrate on the problems faced by our livestock and poultry industries. Their struggle for survival comes at a time when exotic diseases are on the move, production costs are high, and transportation systems are moving at a phenomenal rate.

Let's spend a few minutes thinking about what these diseases may be and how they might affect us. First, we should consider cattle; and, of course, the primary (sometimes known as the world political) disease is foot-and-mouth disease, or apthous fever. Most of the nations on the earth are known as being infected, which means they are not on the Secretary of Agriculture's "free list." U.S. protective laws and regulations are primarily directed at FMD because it is the one which we fear most.

Other diseases of cattle which we class as exotic generally are: rinderpest, Rift Valley fever, East Coast fever, contagious pleuropneumonia, ticks, ephemeral fever, and lumpy skin disease. For the sake of discussion, we should turn our immediate attention to the FMD problem, because the measures necessary to keep FMD out of our country or to eradicate it if it should gain entry are generally adequate to deal with the others.

FMD outbreaks have been discovered nine times in the United States. Three of these were before 1900 and, fortunately, were small and isolated so that little spread occurred even though we had no organized eradication program. Between 1902 and 1929, six additional outbreaks occurred and were eradicated by the slaughter method. Maybe we should say, "But for the grace of God" in explaining our freedom from FMD since 1929. However, I don't want to accept "fatalism" as being the only preventive measure, particularly not since the U.S. Congress passed the 1930 act which gave us authority to take the steps considered necessary to keep it out.

Records in the Department indicate the 1929 outbreak of FMD cost an estimated $1 million. What do you suppose an outbreak in this country would cost today? Of course, no one really knows, but we have some pretty well-documented evidence based on actual costs in the most recent outbreak in the British Isles.

For your information, the Department sent 12 veterinarians to Great Britain to assist with that last outbreak. They needed the help, and we needed the experience. None of our people had gotten experience in eradicating the disease since our joint effort with Mexico dating back to 1949-1954.

Using factual data from the British outbreak and setting up a model in the United States on a comparable scale, we have developed a realistic hypothetical outbreak in the United States. Would you care to guess at the estimated cost of such an outbreak in the United States? Of course, I'm taking unfair advantage of you, but we all realize it would be catastrophic—we just don't realize how much. Would you believe a figure in excess of 3 billion dollars in direct cost? If you would, you would be essentially correct. This, however, would not include billions of dollars of indirect costs, such as loss of income to ranchers, packing houses, and markets.

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[1] Assistant Director, Animal Health Division, Agricultural Research Service, U.S. Department of Agriculture. Speech to the Secretary of Agriculture's Advisory Committee on Foot-and-Mouth Disease, October 18, 1971.

While we were speculating on the subject, we developed a realistic program model on the premise that we could not eradicate the disease for numerous reasons. Therefore, we would have to use vaccine and live with the disease. How would you like to speculate on the annual cost for vaccination?

Of course, the annual cost to vaccinate would be less than the cost of eradication. However, I doubt if you would suspect about 1 billion dollars per year. Yet that is essentially what the figures show, and they were developed in 1968 and do not reflect inflationary costs since that time.

With this as a background, I believe you are ready to consider other exotic diseases which endanger our livestock and poultry industries. African swine fever, African horsesickness, Asiatic (velogenic) Newcastle disease, European fowl plague, Teschens disease, glanders, and dourine, and many more exotic diseases are hammering on our door every day.

In the last few months, Venezuelan equine encephalomyelitis penetrated our south Texas border. We have already committed 17 million dollars to that program, and we don't know yet if or when it can be eradicated. This disease, of course, is the subject of another discussion during your current meeting.

At this point, I believe we can all agree that our best bet is to keep these foreign animal diseases out of our country. That is the job of the import-export people in two divisions. Now I think we should turn our attention to what happens if one of these diseases should gain entry into our country.

First of all, we must and do have a detection system. That system is in operation through our Cooperative State-Federal Disease Control and Eradication Organizations in 50 States, Puerto Rico, and the United States Virgin Islands and through our ANH representatives in Rome, Mexico, and Central America.

The first emergency disease eradication organization was developed following the 1914 outbreak. A definite staff plan was developed and concise instructions developed for people who might be assigned to the emergency operation. That plan essentially included: diagnosis (finding and identifying the disease); quarantines to prevent its spread; disposal of infected and exposed herds of susceptible animals (cattle, sheep, swine, and goats, plus certain wildlife) with indemnification of the owners by the State and Federal authorities; and cleaning and disinfection of the infected premises.

This plan has been the general outline for emergency disease operations since its inception. Naturally there have been a number of new innovations added, such as serological tests and methods of communication. In some cases immunizations have been utilized as adjuncts. However, basically the depopulation of infected and exposed herds has been the U.S. policy.

Following the Joint Commission operation with Mexico, the Department was faced with vesicular exanthema of swine in 1952. Again, this disease was eradicated by the basic slaughter method.

The hog cholera program appears to have an excellent chance to achieve its goals of eradication by December 1972. Vaccines had been the standard control measure for hog cholera since about 1916. Eradication was not possible until all vaccines were done away with.

Our recent experience with VEE in equines, where we utilized modified live virus vaccines, is still in progress. We will likely learn some good lessons from it on vector-borne, arbo-virus diseases.

Now we should analyze our Emergency Disease Eradication Organization (EDEO). The Secretary of Agriculture had delegated this responsibility to the Animal Health Division of the Agricultural Research Service. The organization is composed of a national headquarters, which for convenience conducts its "Test Exercise" from the "Ready Room" located at the Agricultural Research Center, Beltsville, Md.

The field operations of the EDEO are carried out through our Assistant Directors by the State-Federal EDEO organization.

The Ready Room is a converted haymow of a large dairy barn, the lower floor of which is now used for storage of division supplies and publications. The Ready Room is equipped with two maps of every county in the United States, telephone, desks, chairs and other basic supplies. It is not used for other purposes in order to be available when needed. Right now, the remnants of the VEE Emergency Headquarters are using the Ready Room until the Cooperative State-Federal VEE Emergency Program is completed.

Every year the division asks the EDEO organization in each State to carry out a test exercise. In turn, the National EDEO carries out a test exercise which will involve a number of States. We try to use a different group of States and varying problems from year to year.

At this meeting, there will be another presentation pertaining to the possible stockpiling or production of FMD vaccine in the United States, probably at the Plum Island Animal Disease Laboratory. I realize the value of vaccines as an eradication tool. In fact, several of us here in this room were responsible for production or use of vaccine as an adjunct to the Mexican eradication program.

Recently I experienced first hand the mass hysteria which resulted from the entry of VEE into this country. A similar situation could develop if FMD should gain entry into this country. I am firmly convinced that the slaughter program which has served this country so well for over 40 years would never get a fair chance to succeed if a large supply of vaccine is stockpiled.

Recently a meeting was held within ARS where this very problem was thoroughly explored. That group agreed to recommend a national study group of knowledgeable but disinterested people. I hope you can see fit to support that proposal.

None of us want to gamble with our livestock industry. On the other hand, I would seriously hate to be justly accused of saddling our country with the cost of routine vaccination. I don't believe any of us are knowledgeable to the extent that we know the economic results of such a program. However, I dare say it would materially increase the cost of red meats to the family budget.

As your representative who might have to deal with FMD or any other exotic disease, I hope we never have a need for such again. However, like fire departments, we are necessary and fully expect to be used. Two times in the last year I have gone to the field to cope with a real emergency disease situation. The experts don't say if we should happen to get an exotic disease in this country, they say "when". I agree with the latter.

Whether it is me or someone else, you can bet there will be emergency disease operations in the future. We need to be ready—ready with the latest available tools. That means we must continue to improve our surveillance of diseases throughout the world, particularly in Panama and Central and North America.

The livestock and poultry industries are entitled to the best protection we can give them. I honestly believe we can give them good support if we are all dedicated to locating the problem diseases and eliminating them wherever they are found in our area of danger.

I appreciate the opportunity to appear before you and present our problems in the cold light of day before the emergency occurs.

PAPER NO. 9—THE INVOLVEMENT OF BIG GAME ANIMALS IN THE EVENT OF FOOT-AND-MOUTH DISEASE INTRODUCTION INTO THE UNITED STATES

Frank A. Hayes[1]

The shocking consequences of foot-and-mouth disease (FMD) for this Nation's livestock economy have been clearly depicted; and the complexities involved with early detection and eradication offer rather terrifying food for thought. In contrast to the devastating outbreak of FMD in England during 1968, within the continental United States this highly contagious viral entity will not be restricted to a comparatively small land mass. A far greater number of domestic animals will be at risk, and elaborate transcontinental transportation systems and concomitant livestock movements will precipitate problems of staggering proportions. Also unlike England in 1968, another hitherto disregarded factor must receive maximum concern, or all efforts directed toward minimizing the awesome impact of FMD may be hopelessly hamstrung (*5*), (*6*), (*7*).[2]

Reference therefore is made to an estimated 15 million wild, cloven-hooved, free-ranging, FMD-susceptible animals, which extend from coast to coast at varying population levels. This vital aspect of our Nation's natural resources is public property, belonging to the people of this country, and governed and regulated accordingly. More detailed data pertaining to this renewable resource are presented for consideration (table 1).

An initial response to these data by many livestock producers will be reflected by strong sentiments for elimination of FMD-susceptible, wild ungulates. This is easier said than done, since with greater leisure time available sportsmen and associated industries of this Nation now exert far more influence than ever before. A second factor to consider involves the increasing surge of public opinion against killing any form of wildlife, as even now sportsmen themselves are confronted with mounting pressures from powerful "protectionists groups" determined to abolish sport hunting. At present these factions are at odds with each other, but unreasonable demands by livestock interests could combine the forces of well-meaning sportsmen and the growing multitude of "instant ecologists." Such a confrontation would not be in the interest of sound game management or the national welfare. Livestock producers and sportsmen alike—often one and the same—therefore must strive to work together and reach a mutual understanding prior to the inevitable introduction of FMD or other catastrophic foreign diseases.

Aside from the aesthetic and recreational values of big game animals throughout the United States, the economic impact of this resource far exceeds current awareness by the general public. Few cattlemen, for example, realize that the monetary value of one white-tailed deer probably is more than any cow or calf on the premise. Nor are many livestock producers aware that this country's white-tailed deer resource has been appraised at a figure higher than the combined swine and sheep industries (table 2).

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[1] Director, Southeastern Cooperative Wildlife Disease Study, Department of Parasitology, College of Veterinary Medicine, University of Georgia, Athens. This is the first regional diagnostic and research service established in the United States for the specific purpose of investigating diseases of game animals. Participating States include: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia. The program is sponsored and coordinated under auspices of the Southeastern Association of Game and Fish Commissioners; the Federal Aid in Wildlife Restoration Act (50 Stat. 917); and through Contract No. 14-16-0008-777, Bureau of Sport Fisheries and Wildlife, U.S. Department of the Interior.

[2] Figures in italics refer to list of references at the end of this paper.

Table 1.—Population estimates of major big game animals susceptible to foot-and-mouth disease in the event of introduction onto the continental United States[1]

[Alaska and Hawaii not included]

Species	*Legal kill*	*Population estimates*
White-tailed deer	1,361,700	9,345,540
Black-tailed deer	85,140	763,000
Mule deer	584,620	3,179,850
Pronghorn antelope	59,765	331,390
Elk	89,211	386,590
Moose	1,769	26,925
Bighorn sheep	365	13,985
Mountain goat	871	10,020
European wild boar	929	6,600
Peccary	7,621	29,000
Totals	2,191,991	14,092,900

[1] These computations have been condensed from *Wildlife Leaflet #492*, BIG GAME INVENTORY FOR 1969, Bureau of Sport Fisheries and Wildlife, U.S. Department of the Interior, Washington, D.C. 20240.

Table 2.—Some financial considerations of this nation's big game animal resources[1]

[Alaska and Hawaii not included]

Monetary value of *white-tailed deer* based on actual dollars spent by sportsmen for harvest of said species. Equated as follows in terms of national average of $400 per head (*1*):

Value of Legal White-tailed Deer Kill $544,680,000

Value of Total White-tailed Deer Resource $3,738,216,000

Through extrapolation based on the same ultra-conservative figures of $400 per head spent for harvesting *white-tailed deer*, the monetary value thereby placed on the total big game animal resources of the continental United States are as follows:

Value of Legal Big Game Animal Kill $876,796,400

Value of Total Big Game Animal Resource $5,637,160,000

[1] The following figures do not account for the aesthetic and recreational worth of these resources. Statistical studies now are being conducted to include these long-ignored aspects of wildlife conservation, with the end results probably doubling the financial parameters currently being considered.

More specific information on the economic status of white-tailed deer has been extracted and presented in part from a comprehensive report by Cheatum et al. (*2*), where numerous accounts were cited which reflect the economic significance of deer hunting for southern and northeastern States. A small six-county area in Georgia, for example, receives an injection into its economy of more than $500,000 during each deer season, three-fourths of which comes from non-resident hunters (*1*). Three parishes in northeastern Louisiana similarly receive an influx of more than $158,000 during each 5-day deer season (*10*). The Uwharrie Deer Restoration Project, which in 1944 was merely an idea in North Carolina, now enriches the local economy by more than $100,000 each year (*15*).

According to Cross (*3*), hunters in Virginia harvested 24,934 deer during the 1966-67 season. If the figure of $400 per animal (*1*) is applied, deer hunting contributed almost 10 million dollars to the economy of that State in 1966-67. According to the mayor of Crossville, Tenn., wildlife management represents a promiment business in that State (*14*), where deer hunters in the Tennessee Valley area spend approximately 20 million dollars each year enjoying this sport (*4*).

In making an economic comparison of deer to domestic livestock in the Edwards Plateau region of Texas, records from the Kerr Wildlife Management Area show that the net return per animal unit of deer can exceed that of livestock if the deer herd is adequately harvested (*11*). During 1961, 25 ranches consisting of 47,217 acres in Llano County, Tex., derived a combined income of $57,395, or $1.22 per acre, from deer hunters (*13*).

Many northern States have long enjoyed a sizable income from white-tailed deer hunting. In New Hampshire, for example, 1962 hunting values were assessed at over 12 million dollars, of which deer accounted for at least 90 percent (*12*). It was stated, "The importance of deer hunting as a factor in the economy of the nonindustrial 'North Country' was emphasized in 1963. . . A spokesman for the New Hampshire Motel Owners Association, appearing before a legislation, estimated that a 10-day shortening of the season would result in a minimum loss of $100,000-$200,000 to members of his organization. Another motel operator estimated his loss to be $500 per day in addition to the layoff of nine employees. A restaurant owner at Colebrook estimated his income from hunters to be $40-50 per day."

Official reports indicate that deer hunters in New Jersey legally harvested 8,049 deer in 1964 with an average expenditure of $736.50 per deer. This estimate was derived from a deer range of approximately 4,830 square miles or a little over 3 million acres, which averages $2 per acre spent for hunting deer (*9*).

A solution to the problem in question therefore is not nearly so simple as big game animal liquidation in the name of preventive medicine. From a political and sociological point of view, it must be approached in a manner more in keeping with reality, which should behoove domestic livestock and wildlife interests alike to strive for a multiple-use concept directed toward continual production of healthy domestic livestock and big game animals.

Thus far this has been accomplished, as within the past three decades big game animal populations throughout much of the United States have exhibited an almost unbelievable expansion. Wildlife interests subsequently share a tremendous stake in the event of an accidental or purposeful introduction of FMD, as a virtual blanket of susceptible big game animals now practically covers all suitable habitat. The future well-being of the Nation's mammoth livestock and wildlife investments therefore depends upon continued and accelerated cooperation between all parties concerned.

State Game and Fish officials of the United States are becoming increasingly cognizant of the looming threat of foreign animal diseases, which could wreak havoc upon the Nation's multibillion-dollar big game animal resources, with concomitant disaster occurring throughout the entire livestock economy and associated industries. As a result of this growing concern, on October 22, 1968, the Southeastern Association of Game and Fish Commissioners adopted a resolution which afforded the first major merger of efforts between wildlife and domestic animal interests for combating foreign diseases. A modified version of the resolution is quoted (*8*):

"WHEREAS: At any time a devastating exotic animal disease can be accidentally or purposefully introduced onto the Continental United States, which could seriously jeopardize the entire livestock economy;

"WHEREAS: Various forms of game animals can serve in the capacity of unrestrained carriers of a foreign disease transmissible to domestic animals, i.e., white-tailed deer as carriers of foot and mouth disease (FMD);

"WHEREAS: An enemy of this nation could utilize various methods of introducing a devastating foreign disease into wild deer, which could spread rapidly with eventual introduction into domestic livestock;

"WHEREAS: Tremendous expansion of white-tailed deer populations has placed a virtual blanket of these animals over the southeast thus affording an unbroken chain of susceptible animals through which a foreign disease could spread;

"WHEREAS: Early detection of a highly infectious entity is absolutely mandatory for the continued welfare of certain big game animals and domestic livestock;

"WHEREAS: Animal Health Division officials of the Agricultural Research Service (ARS), United States Department of Agriculture (USDA), offer to provide game and fish personnel with training necessary to participate in a program designed for early recognition of potentially dangerous diseases;

"AND WHEREAS: In the event an exotic disease is suspected, the Animal Health Division (ARS, USDA) will afford diagnostic services essential for early detection, with control measures thereafter being delineated in accordance with accepted procedures based on valid scientific data;

"THEREFORE BE IT RESOLVED: That the Southeastern Association of Game and Fish Commissioners support an exotic disease surveillance program in cooperation with the Animal Health Division (ARS, USDA)."

This vital alliance between wildlife and domestic livestock interests was officially enacted July 19-21, 1967, when the Animal Health Division (ARS, USDA) sponsored a regional Foreign and Emergency Disease Surveillance Training Program in accordance with the resolution cited. The program was coordinated by the Southeastern Cooperative Wildlife Disease Study of the University of Georgia's College of Veterinary Medicine and held at the Georgia Center for Continuing Education, Athens. Speakers included numerous internationally recognized specialists from the U.S. Departments of Agriculture and the Interior. Participants consisted of game officials, biologists, and law enforcement personnel representing the following 15 States: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, Virginia, and West Virginia.

Major objectives of the conference are quoted as follows from the program agenda:

". . . to relate and emphasize to Southeastern Game and Fish field personnel the full ramifications of possible foreign disease outbreaks in this country;

". . . to describe the position white-tailed deer and feral swine now will occupy in the event of foreign disease introduction into the southeast;

". . . to familiarize Game and Fish personnel with the elaborate nationwide emergency disease eradication organization of the Animal Health Division, ARS, USDA, and specify the vital role wildlife interests hereafter may play in that program;

". . . to train Game and Fish personnel to immediately recognize and report evidence of a possible foreign disease outbreak;

". . . to establish liaison between attending Game and Fish personnel and the Veterinarian-in-Charge (ANH, ARS, USDA) in their respective States for inaugurating exact reporting procedures for all suspicious cases;

". . . to provide basic information and visual aids with which attending Game and Fish personnel can return to their respective States and relay to co-workers instructions received during the training programs."

After two days of intensive lectures with accompanying visual aids, a test exercise was conducted, which involved Animal Health Division Veterinarians-in-Charge (VIC's) of the 15 States represented. Game management specialists and law enforcement personnel representing each State actively participated in this exercise, whereupon a hypothetical introduction of FMD into wild deer afforded a very challenging occasion for all in attendance.

In followup of the regional program, similar training sessions were conducted at the State level. These encompassed the full complement of technical and law enforcement personnel, which essentially added 150 to 200 trained men per State. These individuals subsequently became well versed on the ramifications of FMD introduction and the urgent need for immediate reporting of suspicious cases involving wildlife or domestic animals. Conservation officials and technical staff simultaneously established direct communications with Animal Health Division officials, State Veterinarians, and the respective State Diagnostic Laboratories.

As a result of these cooperative undertakings, southeastern wildlife interests now are in position to make substantial contributions in the event of FMD introduction into the continental United States. Although concentrated efforts of this type have been essentially confined to the Southeast, at appropriate opportunities governed by critical budgetary limitations, the concept has been projected into other regions of the country. Reference therefore is made to an occasion on November 4, 1970, when a full day meeting was sponsored by the Animal Health Division (ARS, USDA) for key State Game and Fish Officials representative of all regions of the United States, the U.S. Department of the Interior, The Wildlife Management Institute, and the National Wildlife Federation. This briefing was conducted in the National Foreign and Emergency Disease Ready Room at Beltsville, Md., where it was well received by all present.

Since that time, similar programs at the State level have been sponsored in collaboration with several game and fish agencies outside the Southeast, where from 100 to 300 game officials, biologists, and conservation officers were in attendance. (fig. 1). On each occasion the interest expressed far exceeded expectations, and demands by other State game and fish agencies for similar experiences have been extremely gratifying. Requests for training sessions of this kind have been in excess of resources currently available.

In response to these preliminary efforts, the results obtained were vividly manifest during the last National Foreign Disease Test Exercise conducted by the Animal Health Division (ARS, USDA) on May 24-29, 1971. During this full week training session, 34 State Game and Fish Agencies were called upon for assistance in combating a hypothetical introduction of FMD into Idaho and Tennessee, with subsequent spread into other regions of the United States. Of the 34 game and fish agencies contacted, 32 responded and 2,123 trained conservation officers and game biologists with an equivalent number of two-way radioed vehicles were committed to participation in this national training effort. At a later date, officials of the two reluctant States expressed regrets for having not been better informed on the significance of the exercise.

Such overwhelming response without forewarning on a relatively foreign subject reveals the cooperation that can be developed within State Game and Fish Agencies of this country. It also demonstrates the untapped source of manpower that can mean so much in the event of the type national emergency under consideration. It subsequently should be pointed out that all of the men committed for the 1971 Test Exercise were highly trained and well qualified with years of experience in law enforcement, communications, and game management. In addition to manpower and a fleet of two-way radioed vehicles, all State Game and Fish Agencies have varying numbers of light aircraft, helicopters, bulldozers, tractors, farm machinery, trucks, motor boats, drag lines, etc., which could literally mean the difference between success and failure of FMD eradication wherever it becomes essential in the United States.

Agenda: Emergency Disease Eradication Exercise

Location:

March 23 – Highway Building Auditorium (North Half), Lansing, Michigan (Region III)

March 24 – Park Place Motor Hotel, Traverse City, Michigan (Region II)

March 26 – Northern Michigan University, Marquette, Michigan (Region I)

Time: 10:00 AM–4:00 PM

Program

Chairman: Region III Dr. R. I. Blouch
Region I and II Mr. W. G. Youatt

10:00 AM	Welcome	Regional Manager
10:10 AM	Animal Health Division Objective for the Seminar	Dr. W. F. Waddell
10:20 AM	Michigan Department of Natural Resources Objective for the Seminar	Mr. John N. Stuht
10:30 AM	The Threat of Foreign Animal Disease	Dr. N. L. Meyer
11:30 AM	The Threat of Foreign Animal Diseases to Game Animals	Dr. Frank A. Hayes
12:00 Noon	Lunch	
1:00 PM	The Outbreak of Foot-and-Mouth Disease in Great Britain	Dr. N. L. Meyer
2:00 PM	Michigan's Emergency Disease Eradication Organization	Dr. W. F. Waddell
2:15 PM	How Wildlife Organizations Can Fit in with Emergency Animal Disease Eradication Organization (EADEO)	Dr. Frank A. Hayes
2:30 PM	Panel Discussion with Question and Answers	Moderator—Dr. N. L. Meyer
	Dr. B. J. Johnson	Dr. Frank A. Hayes
	Dr. W. F. Waddell	Dr. A. B. Cowan
	Mr. R. MacLean	Mr. W. G. Youatt
4:00 PM	Adjourn	

Where the necessity arises for depopulation of wild animals, the best qualified men for such an assignment already are employed by the agencies that govern the wildlife resources of this country. As an adjunct to the imperative public relations associated with the type of disaster in question, each State Game and Fish Agency employs a staff of information and education specialists, with direct access to the written and spoken mass communications media. This could prove to be a tremendous asset in generating better public understanding and circumventing much controversy inevitably associated with disease eradication.

Although much progress has been made in this important area, accomplishments to date represent only a beginning of that which must be achieved. Well-planned, coordinated efforts must be intensified, for it is imperative the wildlife profession develop more cognition of the awesome impact that FMD can inflict. It is equally essential that domestic livestock interests become more aware of the vital position occupied by those responsible for the big

game investments of this country. Until bridging of this communication gap has been realized, all of the elaborate measures currently planned for early detection and eradication of FMD in domestic animals can be "torpedoed" through lack of coordination between the two spheres of interest responsible for animal health and welfare of the United States.

The ultimate obtainment of objectives discussed at The Secretary of Agriculture's Industry Advisory Committee Meeting therefore may depend upon plans and execution thereof for development of better understanding and working relationships between livestock and wildlife interests. This must be a continuing effort, whereby all parties concerned will become aware of and actively involved in problems of mutual significance.

An accelerated program for mobilization of these existing resources must be funded, but it is a small price to pay when so much is at stake. It will represent an insurance policy of unparalleled value with assurance that such an investment today will pay unprecedented dividends tomorrow.

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PAPER NO. 10--THE VENEZUELAN EQUINE ENCEPHALOMYELITIS (VEE) EMERGENCY OPERATION

By R. E. Omohundro[1]

Venezuelan equine encephalomyelitis (epidemic strain) was first identified in Venezuela in 1936. For reasons not clearly identified, it did not move out of the northern part of South America for over 20 years. In 1969, the disease had leapfrogged over Panama into Central America. Within 2 years after that, the epidemic spread 2,500 miles through Central America and Mexico. Late in June of 1971, the disease jumped the border into the lower Rio Grande Valley of Texas.

An endemic strain of VEE has been isolated for several years from southern Florida where it has not caused clinical disease in horses. However, the first laboratory confirmation of the epidemic strain was on July 9, 1971, from a horse in the gulf area of Texas close to the Rio Grande River. Subsequently, a virus isolation was made from a horse in Live Oak County, Tex., about 150 miles north of the Rio Grande. This horse had actually sickened on June 23. The total number of virus isolations from horses, as of September 8, was 114. Of these, 58 had not been vaccinated against VEE or guinea pig inoculation tests indicated characteristics of the epidemic strain. Thirty-eight isolates were not virulent for guinea pigs, a characteristic of the vaccine strain. For the remaining 18 animals (17 had been vaccinated, and for one, the vaccination history is unknown) the results of guinea pig inoculation tests are not yet available.

VEE virus has been isolated from mosquitoes including those collected in south Texas in the latter part of June.

Isolations of epidemic VEE virus, from horses, mosquitoes, and humans, are all related to southern Texas in the area bounded on the north by Houston, San Antonio, and Del Rio, Tex.

Our Secretary of Agriculture did not have the authority to declare an emergency until the disease was confirmed in the United States. We were aware of course that the Department of Defense vaccine TC-83 had been used and was being used widely in several countries and that its use was apparently successful. However, the vaccine had not been subjected to potency and safety tests which we require in order that a modified live virus vaccine be licensed in this country.

Due to the urgency of the situation, however, on June 25 the Department made the TC-83 vaccine available to horse owners on a voluntary basis in 13 south Texas counties located south of a line from Laredo to Corpus Christi, Tex.

Teams of entomologists from the U.S. Public Health Service's Center for Disease Control (CDC), Atlanta, Ga., began monitoring the larval and adult mosquito populations to determine where and when spraying operations might be conducted. The U.S. Air Force was on alert to provide on short notice aerial spray planes from its base at Langley, Va.

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[1] Assistant Director, Animal Health Division, Agricultural Research Service, U.S. Department of Agriculture.

Heavy rains had fallen in northern Mexico and mosquito populations were building up. In contrast, there were chronic drought conditions on the U.S. side of the border from Brownsville along the Rio Grande to Del Rio, and from Brownsville along the Texas Gulf Coast to Houston. In early July, the drought was broken and rains fell in the lower Rio Grande Valley. Surveillance by CDC entomologists revealed emergence of adult mosquitoes in sufficient quantity to cause a virus-spreading hazard. On July 10, U.S. Air Force planes commenced aerial spray operations, treating over 200,000 acres in Cameron, Hidalgo, and Willacy Counties.

An administrative and control headquarters, established at Harlingen, Tex., coordinated the many Federal and State agencies involved in the control efforts.

Owners and veterinary practitioners were encouraged to report illnesses of horses, and these reports were quickly investigated.

Blood and other tissue samples were obtained from sick horses and submitted to both the Veterinary Sciences Research (VSR) laboratory at Denver, Colo., and to the CDC laboratory at Atlanta, Ga.

The number of sick horses reported and investigated built up rapidly. The early reports were largely from Cameron and Hidalgo Counties, but soon a large number of reports were received from the Corpus Christi and Houston areas and from other regions.

On July 16, 1971, Secretary of Agriculture Clifford Hardin declared a national emergency and requested the Department of Defense to make additional supplies of TC-83 vaccine available to combat the epidemic.

The Emergency Animal Disease Eradication Organization (EADEO) of the Animal Health Division was activated and assigned the primary responsibility for the emergency operation. The basic principles to be carried out in Texas, Arkansas, Louisiana, Oklahoma, and New Mexico were:

a. Disease surveillance and diagnosis, to detect and trace disease spread;

b. Quarantines, to prevent movements of infected horses;

c. Mosquito abatement, to hold down the vector population until horses could develop immunity from the disease through vaccination; and

d. Vaccination of all equines in the 5-State area to provide a large buffer area against further spread of the disease.

Plant Protection Division personnel were assigned to the VEE Emergency Organization to supervise the mosquito abatement operation.

The Entomology Research Division and Public Health Service specialists were assigned to maintain surveillance over the mosquito population buildup along the critical gulf coast areas and to recommend when, where, and how large an area would require treatment.

The Department of Defense supplied to the Department of Agriculture sufficient TC-83 vaccine to vaccinate all equines in the 5-State area (and later in 14 additional States).

On July 18, 1971, State and Federal Animal Health officials met in Dallas, Tex., to work out operational policies for use of the vaccine in the 5-State area including the use of fee-basis veterinarians.

A Regional VEE Headquarters office to service the States concerned was made operational in Houston, Tex., on Monday, July 19. The following day USDA placed a Federal quarantine on Louisiana, Arkansas, Oklahoma, and New Mexico. Texas had been under Federal quarantine since July 13. The site selected was a large motel near Houston intercontinental Airport and on U.S. Interstate Highway 45.

On July 21, the mosquito abatement program was expanded. Two aerial applications were initially planned to knock out the "salt marsh" and other mosquitoes in a 5-10 mile wide band along the coast from Cameron County, Tex., to Cameron Parish, La. The vector control efforts were designed to buy time until 85 to 90 percent of the equine population was vaccinated.

Civilian and military mosquito surveillance teams were dispersed along the coast to do daily mosquito counts and report their results to Houston. The rice harvest was beginning in a portion of the coastal area and field drainage for the harvest tended to reduce mosquito populations by eliminating breeding places. However, rice farmers flooded their fields following harvest in preparation for a second crop resulting in a "bumper" crop of fresh water mosquitoes.

Because of this, the spray area was widened to 30 miles along the entire Texas gulf coast. This area was scheduled for one and probably two applications. A dry period of about 10 days developed, reducing the mosquito emergency and delaying the need for a second spray application. By the time the rains resumed, over 90 percent of the horses south of the Corpus Christi had been vaccinated for the required 14 days, thereby eliminating the need for a second application in that area. However, a second application was required north of Corpus Christi into Cameron and Calcasieu Parishes in Louisiana.

On July 26, 1971, the Secretary of Agriculture authorized the use of Federal vaccine and fee-basis payment for its application in six additional States—California, Arizona, Mississippi, Alabama, Georgia, and Florida. While no evidence of the disease had appeared outside of south Texas, all of the additional States either bordered on Mexico or the Gulf coast of Mexico where spread might occur.

Extensive surveillance of mosquitoes and wildlife throughout the 5-State area was maintained by CDC and through the use of 10 U.S. Army surveillance teams dispersed throughout the States involved. These teams submitted mosquito collections to Ft. Detrick, Md., and tissues from animals to CDC in Atlanta, Ga., for virus isolation and serology work.

Teams of epidemiologists from CDC, the U.S. Army Veterinary Corps, and cooperating State and Federal animal health staffs investigated all reports of horses showing signs of a central nervous system disease. Tissues and blood were collected and sent to the laboratories.

The VEE Headquarters moved from Houston to the Animal Health Division's emergency disease "Ready Room" at Beltsville, Md., effective August 23, 1971. The program was virtually completed in the original five States (Texas, Louisiana, New Mexico, Oklahoma, and Arkansas) and nearly completed in the other six States (California, Arizona, Mississippi, Alabama, Florida, and Georgia).

On August 24, Secretary Hardin added eight additional States to the area scheduled to receive free vaccine and fee-basis administration of the vaccine. These States were Tennessee, Kentucky, South Carolina, North Carolina, Virginia, Maryland, New Jersey, and Delaware.

Epidemiological studies are also underway. These involved the Departments of Agriculture, Defense, and Health, Education, and Welfare. Plans are nearly complete for an extensive surveillance program to be underway prior to next year.

As of this date (September 20, 1971) there have been reports from CDC identifying 84 human cases, none fatal.

PAPER NO. 11--AFRICAN SWINE FEVER

By Norvan L. Meyer

African swine fever (ASF) has the potential to decimate U.S. swine herds. It is a killer disease for which no vaccine or treatment are known. ASF is clinically indistinguishable from hog cholera. The post-mortem lesions of African Swine Fever and hog cholera are also similar. In other words, you cannot tell the difference between the two diseases without laboratory tests. However, when the two diseases are compared, lesions of African swine fever are usually more severe.

African swine fever is highly contagious and is usually fatal. It is caused by a virus and affects only swine. Some types of swine, such as the wild boar found in Africa and the javelina found in Southwestern United States, are not susceptible. The wild boar may become a symptomless carrier after exposure.

There is no effective vaccine for African swine fever and no effective treatment is known. If an outbreak occurs, quarantine of infected and exposed swine and eradication by slaughter is the only known effective method to eradicate the disease. Occasionally, an animal may recover from the disease. Such animals often remain carriers for life.

African swine fever has been known to exist for about 70 years in eastern and southern Africa. In 1957, the disease invaded Portugal and Spain. Three years later, free-ranging hogs in Spain quickly spread the disease to community herds. In spite of vigorous eradication programs in Spain and Portugal, the disease has not been eradicated there. A modified live vaccine was developed and used in Spain during the early 1960's. Unfortunately, a large percentage of the vaccinated animals became sick, many died and those that lived were not permanently immune.

In 1964 and 1967, african swine fever spread into France but was apparently successfully eradicated. Italy reported an outbreak in 1967 and slaughtered many thousands of swine in an effort to control and eradicate the disease. No outbreaks have been reported in that country for more than a year.

The disease had never been diagnosed in the Western Hemisphere until Cuban authorities admitted its presence in their country in late June of this year. According to the Cubans, African swine fever had not been reported in that country until May 6, 1971, when the first outbreak was detected. Before the identity of the disease could be established, it was necessary to get diagnostic assistance from Canada and from Russia. Identity of disease was established June 17, 1971. The Government of Cuba then set up a commission for combating the disease. The commission was responsible for "liquidation of the disease in the National Territory and to obviate the possibility that other countries of the world other than Cuba would be affected".

The first and only information I have seen from the Cuban Government reported that there had been 33 positive diagnoses of the disease, all in the provice of Havana. Later, unofficial reports from the Pan American Health Organization indicate the last outbreak occurred August 6, 1971. The first outbreak of African swine fever occurred on a Government hog farm of about 11,000 swine. This farm received animals from the majority of the "State" hog-producing units and is located in the Province of Havana.

Swine production in Cuba is conducted on private premises and on State farms. The State directs breeding through the National Pork Union, a division of the National Institute for Agrarian reform. On private premises, hogs are raised mainly for personal consumption. The number of pigs per unit on private farms is therefore limited. A number of persons, in spite of sanitary regulations which prohibit the practice, maintain pigs in urban and suburban areas.

Until 1964, hog cholera, the Cubans say, was considered an epizootic disease of pigs on both private and state farms. According to the Cuban report given at the World Veterinary Congress in Mexico last summer, systematic hog cholera vaccination on state farms made possible control so that the disease occurred only as sporadic outbreaks. In the private sector, the disease is found with greater frequency. In spite of the fact that vaccine is provided free, private owners reportedly did not systematically use the vaccine. The vaccine was called strain K and is provided by Red China.

The Cuban report states that the following measures were taken to eliminate the disease in Havana Province:

1. Quarantine of the swine population of Cuba, in both the State and private sector.

2. A complete census of swine in the Province of Havana (463,322).

3. Elimination of all foci of infection by slaughter of infected and exposed animals, with disposition of carcasses by incineration and burial.

As of about August 1, there had been 33 foci of infection with 32,524 animals of which 12,173 died and 20,351 were slaughtered.

4. The elimination of suspect cholera and ASF by slaughter, incineration and burial.

5. Slaughter of all swine in a 5 kilometer band in the provinces of Pinar Del Rio and Matanzas along their borders with the Province of Havana.

6. Sacrifice of all the privately-owned swine in the Province of Havana. Each owner in the Urban area was authorized to consume 3 pigs and each owner in the rural area was authorized to consume 5 pigs. The remaining animals were consigned to slaughter for industrial processing into canned and sterilized meats.

Consumption in the urban zone was 105,652, consumption in the rural zone was 100,000 and 177,670 were processed and indemnified by the state for a total of 383,322.

7. Slaughter of the state owned hogs in the Province of Havana, 29,923 as of July 25, 1971.

8. Control of the entry and departure via railways and roads, with a requirement for registration and disinfection.

9. Control of vaccination for hog cholera and erysipelas in the entire country. All hogs are vaccinated for cholera and whenever necessary for erysipelas.

10. Organization of a vigilance program at the National level.

The Cuban report lists a number of other control procedures on infected premises. For instance: (1) cleaning and disinfection of infected premises, (2) elimination of dogs and cats, (3) plowing under and disinfection of grasses on infected premises, (4) incineration of wood and other construction materials on infected premises, and (5) development of recovery procedures concerning test animals, repopulation procedures, insect control, and rodent control procedures.

I have only hit the high spots of the eradication program as it was reported by the Cubans. If all control procedures outlined in the report are carried out, Cuba should be able to eradicate the disease. I hope they are successful, but even if they are, the problem doesn't end there. Spain, Portugal, and parts of Africa remain infected. The disease may also be present behind the Iron Curtain. The disease is on the move and may sometime reach the United States.

We have increased the intensity of surveillance at ports of entry to prevent entry of the disease. We have encouraged Mexico, Central America, and Panama to take similar steps. We have provided hog cholera and African swine fever diagnosis training for the same group of countries.

The hog cholera eradication program has provided an opportunity to test our ability to seek out and eradicate hog cholera. We know how to carry out eradication procedures. Early reports of all suspicious cases of hog cholera or African swine fever are essential to quick and comparatively economical eradication. I urge you all to carry the message—African swine fever is on the move—Eradication by slaughter is the only known effective procedure—Early reports are essential.